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Coal Mining and Environment: A Case Study of Dorli Opencast Coal Mines

National Institute of Advanced Studies
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A Case Study of Dorli Opencast Coal Mines

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Cover photo: (Front cover) A pit lake in a coal mine
(Back cover) A dragline in an opencast coal mine in India

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ABBREVIATIONS

AAQMS	Ambient Air Quality Monitoring Stations
AOI	Area of Interest
APHA	American Public Health Association
BIS	Bureau of Indian Standards
BOD	Biological Oxygen Demand
BZ	Buffer Zone
COD	Chemical Oxygen Demand
CZ	Core Zone
CPCB	Central Pollution Control Board
DO	Dissolved Oxygen
EC	Electrical Conductivity
EEP	Energy & Environment Program
FY	Financial Year
GW	Ground Water
MMDR	Mines and Minerals Development and Regulation
MOC	Ministry of Coal
MOEF&CC	Ministry of Environment, Forest and Climate Change
MT	Million Tonnes
NAAQS	National Ambient Air Quality Standards
OB	Overburden
OCM	Open Cast Mines
OSMRE	Office of Surface Mining, Reclamation, and Enforcement
PM	Particulate Matter
SCCL	Singareni Collieries Company Limited
SERB	Science & Engineering Research Board
SMCRA	Surface Mining Control and Reclamation Act
SW	Surface Water
TDS	Total Dissolved Solids
WPI	Wholesale Price Index
WQMS	Water Quality Monitoring Stations

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1. Introduction

Coal continues to fuel approximately three-fourths of the country's electricity generation in FY 2018-19. In addition to electricity generation, coal is also a vital input for other core industries like steel and cement, which play a critical role in the country's development. Notwithstanding the optimism over renewables displacing fossil fuels rapidly, coal will continue to dominate India's electricity generation at least for a couple of decades more. Coal mining activity has both positive and negative impacts in the areas of operation. It has an economic dividend in terms of infrastructure development of the local area and provision of employment and business opportunities for local people. In India, opencast mining of coal has grown by leaps and bounds over the years, while environmental and social consciousness has also increased. Increased public awareness and developments in thinking of people over the last few years have also resulted in ever-increasing demands for Sustainable Development. Given this scenario, the coal sector must incorporate sustainability (social aspects, economic dependencies, and ecological sensitivities) into the mining process right from the planning stage.

Increased public awareness and developments in thinking of people over the last few years have also resulted in ever-increasing demands for sustainable development. All developed countries with large opencast coal mines (specifically, USA, Australia, South Africa Governments) have realized that they have direct responsibility for defining and ensuring comprehensive Mine Closure within the broader context of the issues of "social/economic equality" and "sustainable development." This recognition of a broader context of Mine Closure has greatly expanded the scope of government responsibilities and needed actions. In all these countries, the trend is most certainly toward developing a more comprehensive approach, to ensure acceptable mine closure.

As early as 1977, the US Congress declared *inter alia* in its Statement of Findings and Policy in relation to the Surface Mining Control and Reclamation Act that**:**

"Many surface mining operations result in disturbances of surface areas that burden and adversely affect commerce and the public welfare by destroying or diminishing the utility of land for commercial, industrial, residential, recreational, agricultural, and forestry purposes, by causing erosion and landslides, by contributing to floods, by polluting the water, by destroying fish and wildlife habitats, by impairing natural beauty, by damaging the property of citizens, by creating hazards dangerous to life and property by degrading the quality of life in local communities, and by counteracting governmental programs and efforts to conserve soil, water, and other natural resources."

In the four decades since the Surface Mining Control and Reclamation Act ("**SMCRA**") was passed by the US Congress in 1977, this Act has had a major impact on the coal industry. Under the SMCRA, an Authority named Office of Surface Mining (now renamed as Office of Surface Mining, Reclamation, and Enforcement ("**OSMRE**") has been set up at the Federal level in the USA, which governs surface coal mining in Federal Lands and Indian Reservations, while most States have established their own statutes and regulatory bodies in consonance with SMCRA suitably adapted to local conditions. At all U.S. coal mining operations, detailed reclamation plans must be approved by the OSMRE (or its State equivalent) before mining begins, and reclamation bonds are posted by coal mine owners to ensure successful completion of the process. OSMRE or the equivalent Regulatory Authority in each State has the necessary multi-disciplinary teams and is fully empowered to perform all key regulatory and enforcement functions with respect to surface coal mines in the USA. Since the enactment of the Surface Mining Control and Reclamation Act (SMCRA) in 1977, coal mine owners in the U.S. have reclaimed more than one million hectares (Ha) of mined-out land for beneficial uses. In addition, the Federal and state governments have facilitated the reclamation of more than 40,500 Ha mined-out land of coal mines abandoned before the enactment of the SMCRA.

1.1. Indian scenario

The issues caused by land acquisition for opencast coal mines are exacerbated in India given the high population and population density in the country. The negative perception of people in relation to opencast coal mines is also due to a large number of coal mines abandoned without proper reclamation and restoration. As on 1st April 2015, 198 coal mines were reported to be closed, abandoned or discontinued, largely in Jharkhand, West Bengal, Madhya Pradesh, and Chhattisgarh. Several of these coal mines have been closed or abandoned prior to the issue of the Mine Closure Guidelines by the Ministry of Coal in August 2009. As a result, the then mine owners have not provided for the costs of closure of these mines.

While mining operations have positive economic impacts on the local area in terms of infrastructure development and provision of employment and business opportunities, adverse effects of coal mining on the ecology of the local area are also well known. The changes in the ecosystem of the region are particularly significant in the case of opencast coal mines, which account for more than 94 percent of the coal produced in India. Therefore, till March 31, 2019, the Ministry of Coal (MOC) has approved mine closure plans for 583 coal/lignite mines based on the of mine closure guidelines by MOC in August 2009. From 2011 onwards, the mine closure plans also formed an integral part of the statutory Mining Plans approved by MOC for all coal mines in India. Since an approved Mining Plan is critical to quantify the impact of the proposed surface coal mine on the forest and environment, MOEF&CC has stipulated (in the Terms of Reference for Environmental Impact Assessment for coal mining projects) that the details related to the mining scheme (e.g., reserves, ultimate working depth, approved rated capacity, calendar plans of production) included in the Environmental Management Plan must be based on the approved Mining Plan.From 2018 onwards, a copy of the MOC's letter approving the Mining Plan is now a mandatory supporting document to apply for prior environmental clearance for a mining project.

Section 20(A) of the MMDR Amendment Act, 2015 ("MMDR Act, 2015") empowers the Central Government to issue directions on any policy matter in the National Interest, inter alia, for the scientific and sustainable development and exploitation of mineral reserves, and to *promote restoration and reclamation activities so as to make optimal use of mined-out land for the benefit of the local communities*. Since mining operations entail a temporary diversion of land for mining and allied activities, after which the mine owner must rehabilitate the mined-out land for beneficial use of the local communities. In order to safeguard the interests of the local communities by ensuring that the mine closure activities are actually carried out as per the approved Mining Plan, the owner of an opencast coal mine in India must deposit Rs.900,000 per hectare of the total project area on an annual basis (to be escalated @ 5% CAGR i.e. Compounded Annual Growth Rate from April 2019 onwards) into an escrow account which is managed by the Coal Controller. These funds are intended to provide some security to cover the cost of mine closure in case the mine owner fails to complete the approved closure activities. In the case of mining plans submitted to MOC for approval from December 16, 2019 onwards, the flat rate of Rs.900,000 per annum will also be escalated using the Wholesale Price Index (WPI).

The ability to successfully rehabilitate mined-out areas has now become fundamental to the coal industry's social license to operate. Therefore, there is a need for the Indian coal industry to adopt a more practical approach based on detailed activity-based costing to mine closure planning which requires a multi-disciplinary organization dedicated to understanding the geological, social, biological, forestry, hydrological, hydrogeological, and environmental aspects of mine closure and rehabilitation.

1.2. Background to this study

In 2018, the Energy & Environment Program (EEP) at NIAS commenced a study of the Dorli I and Dorli II Opencast Coal Mines (OCMs) owned by Singareni Collieries Company Ltd (SCCL) as part of a research project funded by Science & Engineering Research Board (SERB) in the Department of Science & Technology in the Government of India. Subsequently, this study extended to two other opencast coal mines in the Dorli-Bellampalli coalfield in order to study the impact of opencast coal mining on the environment in this thinly populated area which is devoid of any other industrial activity. Therefore, the impact of operating coal mines on the environment could be studied without the confounding effects which can be created by other sources of pollution like, industries or vehicular traffic. Further, discussions with the ever-helpful SCCL management led by the Director (P & P) revealed their openness to explore alternative mine closure strategies with the overall objective of ensuring that the mined-out land is used for the benefit of the local communities. Therefore, NIAS plans to pursue this field-based research on coal sustainability which is a topic of great importance for India.

2. Study area

The State of Telangana which has a population of 3,50,03,674 within an area of 112,077 km^2 was formed on 2nd June 2014 as the 29th State of India (Government of Telangana, 2019). The area selected for this study is bound by Latitudes 19°17'6.29"N to 19°15'19.33"N and Longitudes 79°10'21.36"E and 79°21'42.72"E and covers an area of 163 km^2. The study area is the part of Bellampalli Coal belt of Godavari Valley Coalfield situated in the Komaram Bheem district of Telangana State. The study area consists of four Opencast Coal Mines (OCMs) namely Dorli-I & II, Khairagura Opencast Expansion Project and Bellampalli Open Cast-II Expansion Project. All these mines belong to M/s. Singareni Collieries Company Limited (SCCL) a Government Company under the Companies Act. The Tiryani forest is at the north western side of the study area and Golleti hills in the south eastern part. The mines along with their overburden (external dump areas) and the respective Ambient Air Quality (AAQ) and Water Quality Monitoring (WQM) stations are depicted in **Figure 1.**

In most cases, the boundaries of a coal mine (and by extension, its economic reserves) get extended continually due to improvements in technology as well as market conditions. Therefore, coal mines are sometimes operated as "relay projects" where the overburden from one coal mine is dumped into the void created by extracting coal from an adjacent coal mine. However, the two Dorli coal mines form an

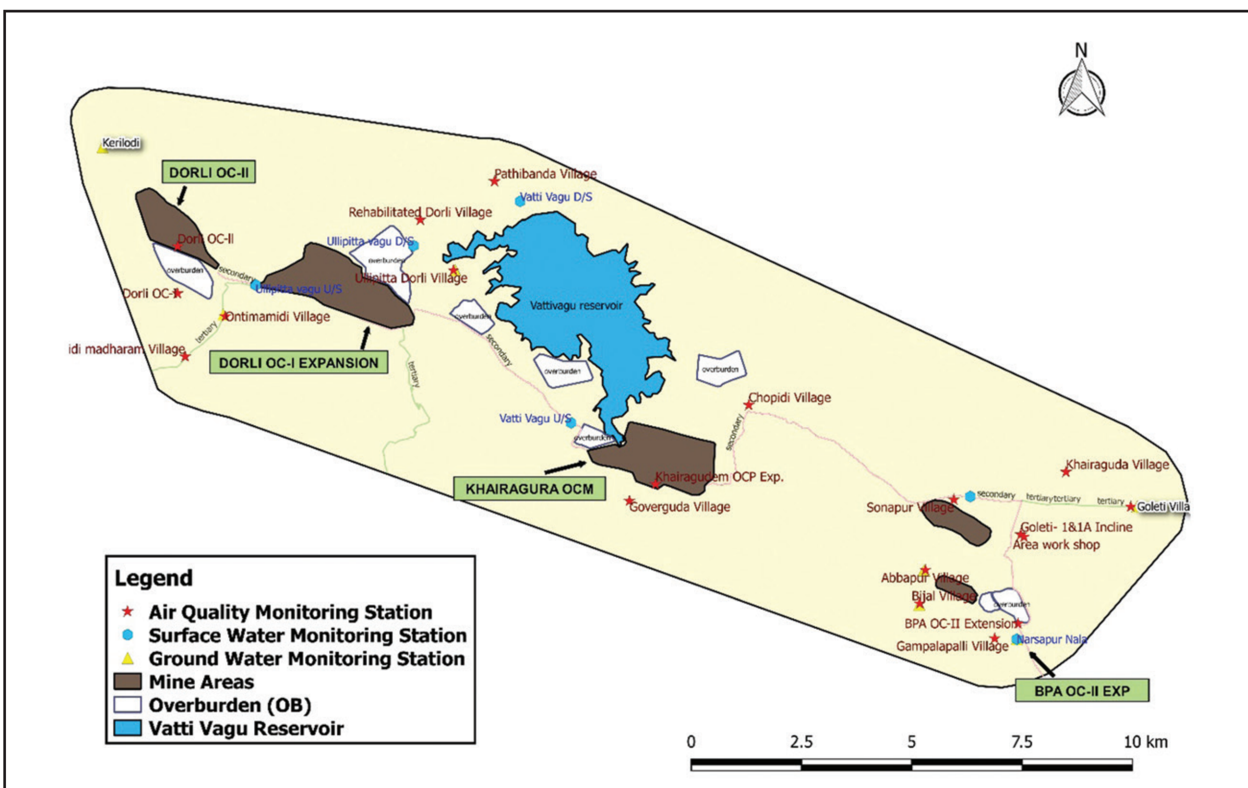

Figure 1: Location of coal mines and their respective Ambient Air Quality and Water Quality Monitoring stations in the Komaram Bheem district of Telangana State

almost unique example of mines where relay projects could not be envisaged due to want of forest clearance for further extension.

Table 1: Details of study area:
Dorli- Bellampalli Coalfield in the Komaram Bheem, district

Sl. No.	Study Area	Date of opening	Date of closure
1.	KRG Open Cast Expansion Project	01/07/2006 01/06/2015	-
2.	Bellampalli Open Cast Expansion Project (BPA OC-II)	01/04/2006 01/4/2016*	-
3.	Dorli-I	01/12/2007	31/03/2019
4.	Dorli-II	11/07/2011	01/04/2017

*Mining operation in BPA OC –II were interrupted between 01/04/2012 and 31/03/2016, they resumed only in 2017

2.1. Geography and Meteorology

The State of Telangana is located in a semi-arid area that receives about 700 mm of rainfall mainly during the monsoon season which starts in June and lasts until September (Government of Telangana, 2019). A dry, mild winter starts in late November and lasts until early February during which the average temperature is 22-23°C. The topography of the study area is plain, and the mean sea level elevation varies in a narrow band between 218 and 450 m (Planning Department, GoT, 2016)

The micro-meteorological scenario in the area is described in the Environmental Impact Assessment (EIA) reports submitted to the Ministry of Environment, Forest and Climate Change (MoEF&CC) and/or the Telangana State Pollution Control Board (TSPCB) by a Government company - Singareni Collieries Company Limited (SCCL). The local micrometeorological station installed in the office of the General Manager of SCCL's Bellampalli area has recorded temperatures of 10 - 46°C (mean 28.7°C), relative humidity values of 7 - 78 % (mean 46%), and total annual rainfall of 501 mm. The predominant wind directions are from the SSE, SW, and WNW directions with wind speeds ranging between 0.5 and 8.8 m/s.

2.2. Data Collection and Analysis

The study includes analysis of data from 23 Ambient Air Quality Monitoring Stations (AAQMS) and 13 Water Quality Monitoring Stations (WQMS) submitted to the MoEF&CC and the Telangana State Pollution Control Board (TSPCB) by the SCCL coal mines to comply with the environmental clearances under the Environment Protection Act (e.g., SCCL, 2019a; 2019b; 2019c; 2019d; 2019e; 2019f; 2019g; 2019h; 2019i; 2019j; 2019k). Additional data was collated from compliance reports submitted by the SCCL which included bi-weekly monitoring data from five core zone air sampling stations and seven buffer-zone air sampling stations.

As per MoEF (2010) guidelines, the core zone in the mining sector is confined to the mining lease area (within which mining operations are carried out), while the buffer zone is the area falling within a distance of 10 km around the periphery of the core zone in case the area of the core zone exceeding 0.25 km^2. The AAQ monitoring stations referred to in this Study have been installed and monitored by SCCL as per CPCB/MoEF guidelines (CPCB, 2011).

As per the CPCB monitoring norms, four ambient air quality monitoring stations should be established in the core zone as well as in the buffer zone for monitoring Particulate Matter (PM_{10} & $PM_{2.5}$), as well as gaseous pollutants SO_2 and NO_2. The locations of these stations are based on the meteorological data, topographical features and environmentally and ecologically sensitive targets, and finalised in consultation with the Telangana State Pollution Control Board (TSPCB).

As per the air monitoring guidelines, a High-Volume Sampler (HVS) is used to measure ambient air PM_{10} concentrations by drawing in air through a size-selective inlet and a Glass-fiber filter (size of 20.3 X 25.4 cm) at a flow rate of 1132 L/min. A Central Pollution Control Board (CPCB) approved air sampler is used to measure $PM_{2.5}$ concentrations in the ambient air, by sucking in air at a constant volumetric flow rate of 16.7 L/min with a specially-designed inertial particle-size separator where the $PM_{2.5}$ particles are collected on a 47 mm polytetrafluoroethylene (PTFE) filter (CPCB, 2011).

Water sampling and analyses methodology

Assessment of water quality in the study area was conducted for two categories of water samples:

1. Ground water quality (IS 10500)
2. Surface water quality (IS 2296).

Sampling was conducted over four seasons corresponding to the four quarters of a year:

1. June-August: Monsoon
2. September-November: Post- monsoon
3. December-February: Winter
4. March-May: Summer

The analyses were conducted as per the standard methods for examination of water samples described by American Public Health Association (APHA, 1992).

3. Year wise Coal production in Dorli-KRG region

As per SCCL's production records, the total coal production and Overburden (OB) volumes mined from the opencast coal mines in the study area are shown in Figure 2. Between Financial Year (FY) 2012-13 and FY 2018-19, the annual coal production from opencast coal mines in this area increased from 4.9 million tonnes (MT) to 6.3 MT (SCCL, 2017; 2019k; 2019l; 2019m). In addition, the volume of overburden (non-coal material to be excavated to extract the coal in opencast mines) excavated from these opencast coal mines increased from 35.9 million cubic meters (Mm^3) to 47 Mm^3. The total excavation from the opencast mines in the study area increased from 39 Mm^3 during FY 2012-13 to 51 Mm^3 in FY 2018-19 as shown in Figure 2. However, the highest coal production and overburden removal quantities were recorded in FY 2017-18 (6.9 MT and 58.1 Mm^3 respectively) leading to a record high excavation of 62 Mm^3 from the opencast coal mines in this area during that year.

Table 2: Mine wise coal and overburden production from the Dorli-Bellampalli coalfield

Coal Production (MT)					
Year	Bellampalli OC-II	Khairagura Opencast Expansion	Dorli-I OCM	Dorli-II OCM	Total
2012-13	-	2.26	1.613	0.997	4.87
2013-14	-	2.97	1.092	0.999	5.06
2014-15	-	2.714	1.146	0.225	4.08
2015-16	-	3.371	2.166	0.847	6.38
2016-17	0.37	3.128	2.626	0.279	6.40
2017-18	0.99	3.414	2.5	-	6.90
2018-19	0.847	2.911	2.498	-	6.25
Overburden in Million cubic meters (Mm^3)					
Year	Bellampalli OC-II	Khairagura Opencast Expansion	Dorli-I OCM	Dorli-II OCM	Total
2012-13	-	10.61	13.55	11.7	35.86
2013-14	-	19.49	6.811	9.4	35.70
2014-15	-	28.46	14.82	3.13	46.41
2015-16	-	24.71	22.7	5.05	52.46
2016-17	6.821	20.088	15.77	1.26	43.93
2017-18	6.648	29.098	22.311	-	58.05
2018-19	7.11	27.48	12.638	-	47.22

(Sources: (SCCL, 2017; 2019k; 2019l; 2019m)

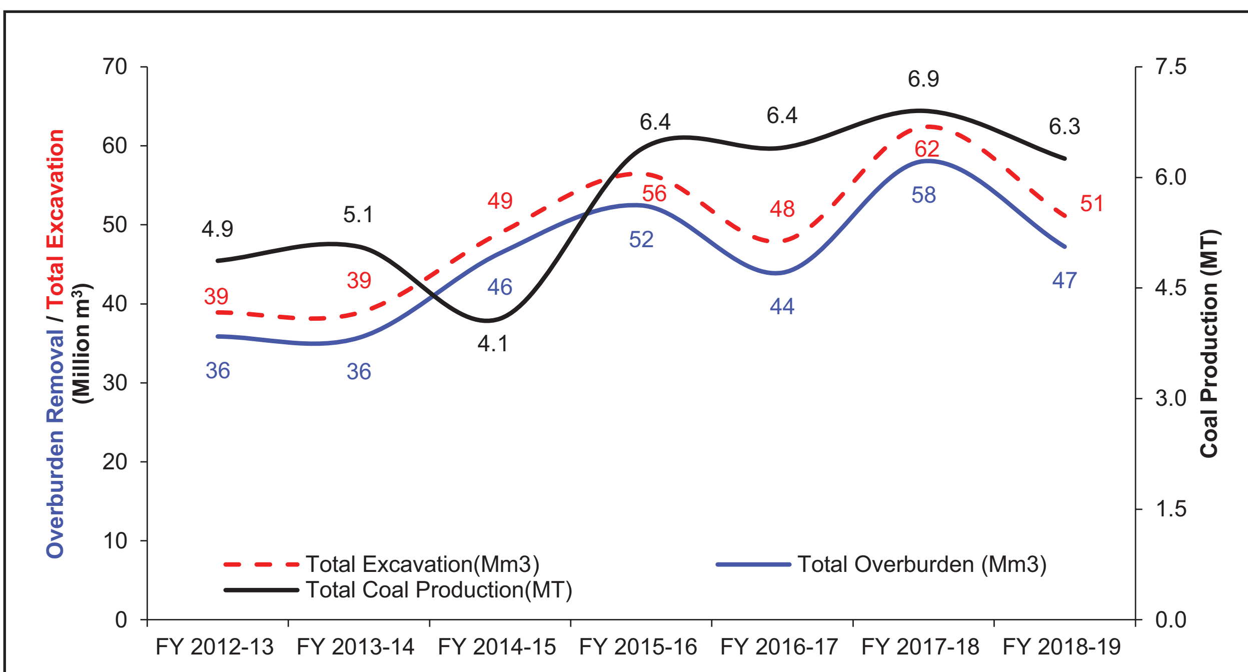

Figure 2. Total coal and overburden production from Opencast Coal Mines in the Dorli-Bellampalli Coalfield. (SCCL, 2017; 2019k; 2019l; 2019m)

4. Water Environment

4.1 Seasonal quality of surface water and groundwater

Surface and ground water exhibit their chemical signatures which are produced as result of several factors such as rainfall, rock-water interaction and several anthropogenic inputs. The surface locations from where surface water samples were drawn by SCCL for analysis are shown in Figures 3-8. The temperature of the groundwater samples over different locations around the Dorli-Bellampalli OCMs ranged between 22-25.3°C with an average of 23.5°C. The pH values in surface water and ground water samples collected around Dorli-I and Dorli-II OCMs varied from 7.5 to 8.5 (average = 8.0) and 7.2 to 8.1 (average = 7.5), respectively. Throughout the year, all the pH values of the water samples were found to be within the permissible limit of 8.5 (BIS 2004).The electrical conductivity (EC), a good indicator of the salinity ranged between 123 to 640 mmhos/cm (average = 283 mmhos/cm) in the surface water and between 202 to 1710 mmhos/cm (average = 1060 mmhos/cm) in groundwater. The maximum Electrical Conductivity (EC) values in the groundwater (GW1) were recorded during post-monsoon, but within the safe limits. In the surface water, the Dissolved Oxygen (DO) values ranged between 4.2 to 6.4 mg/L (average = 4.8 mg/L), showing optimal aeration. Slightly higher DO values were observed in the samples collected from SW1 in the study area during post-monsoon. These values exceeded the permissible range of 4 - 8 mg/L (BIS 2004), and may be due to the mixing of large amounts of atmospheric oxygen in the surface water.

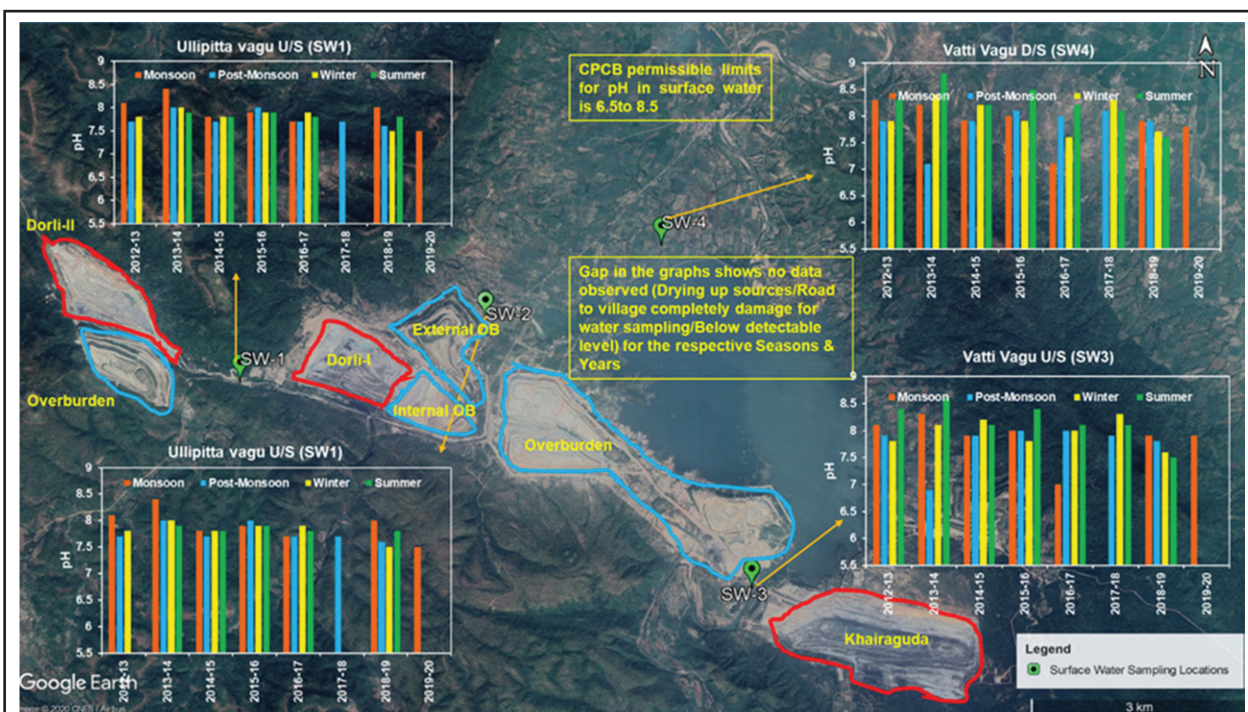

Figure 3: Seasonal variations in pH of surface water around Dorli OC-I, OC-II and Khairagura OCMs

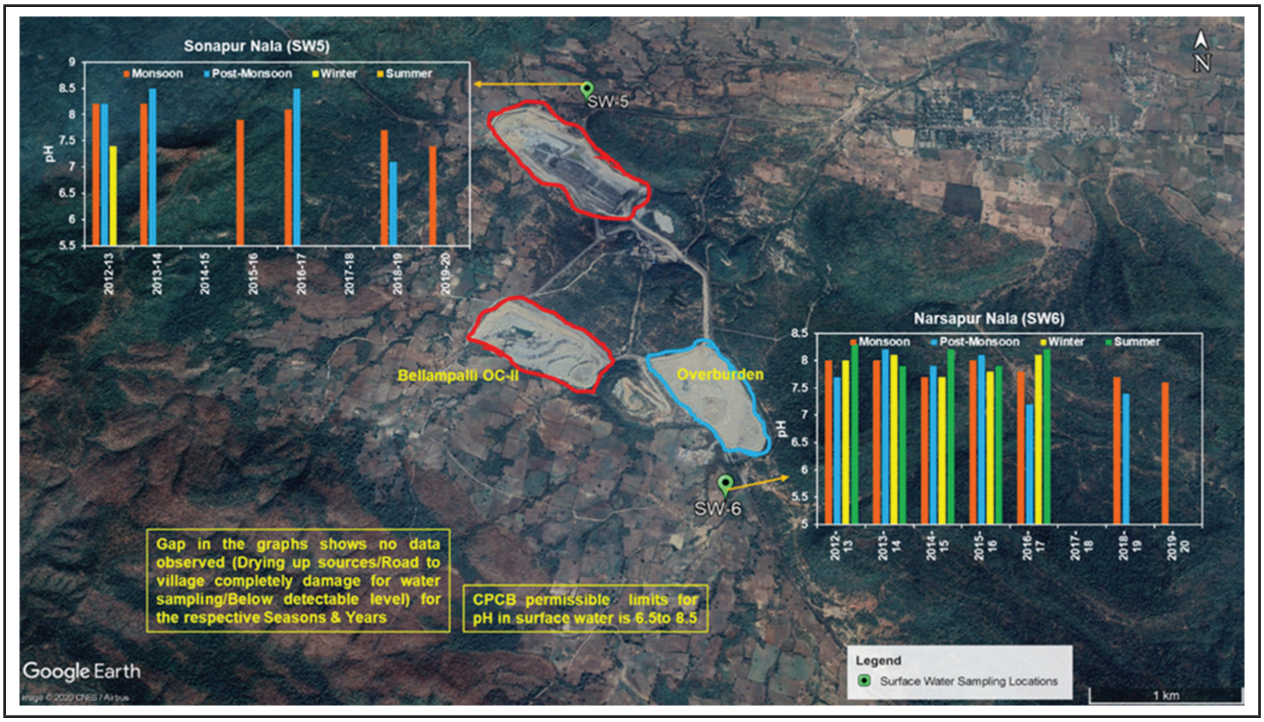

Figure 4: Seasonal variations in pH of surface water around Bellampalli OC-II

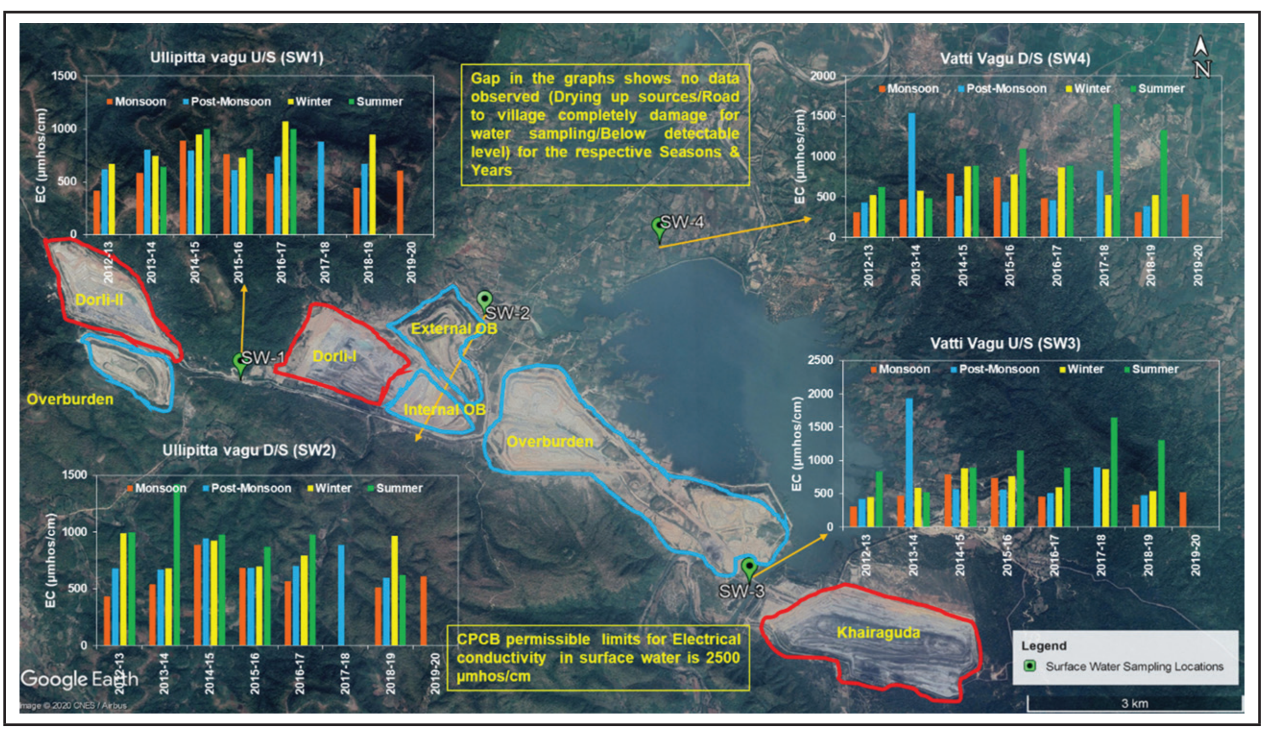

Figure 5: Seasonal variations in Electrical Conductivity (µmhos/cm) of surface water around Dorli OC-I, OC-II and Khairagura OCMs

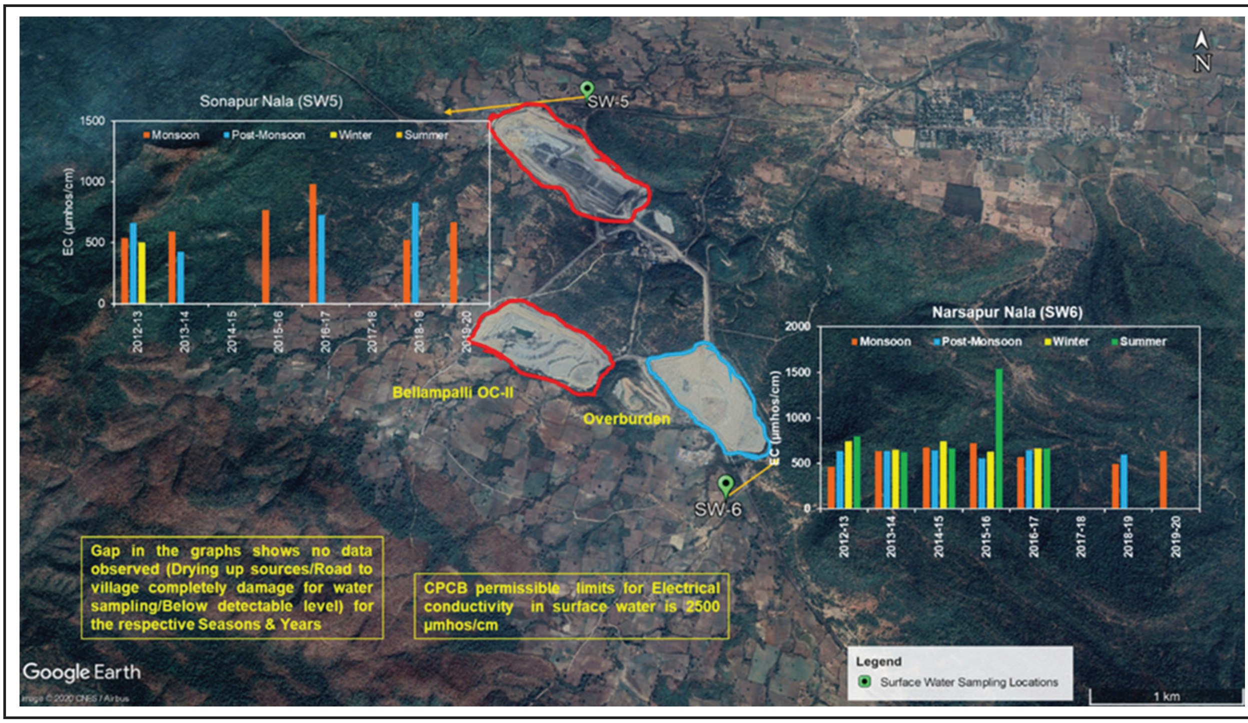

Figure 6: Seasonal variations in Electrical Conductivity (µmhos/cm) of surface water around Bellampalli OC-II

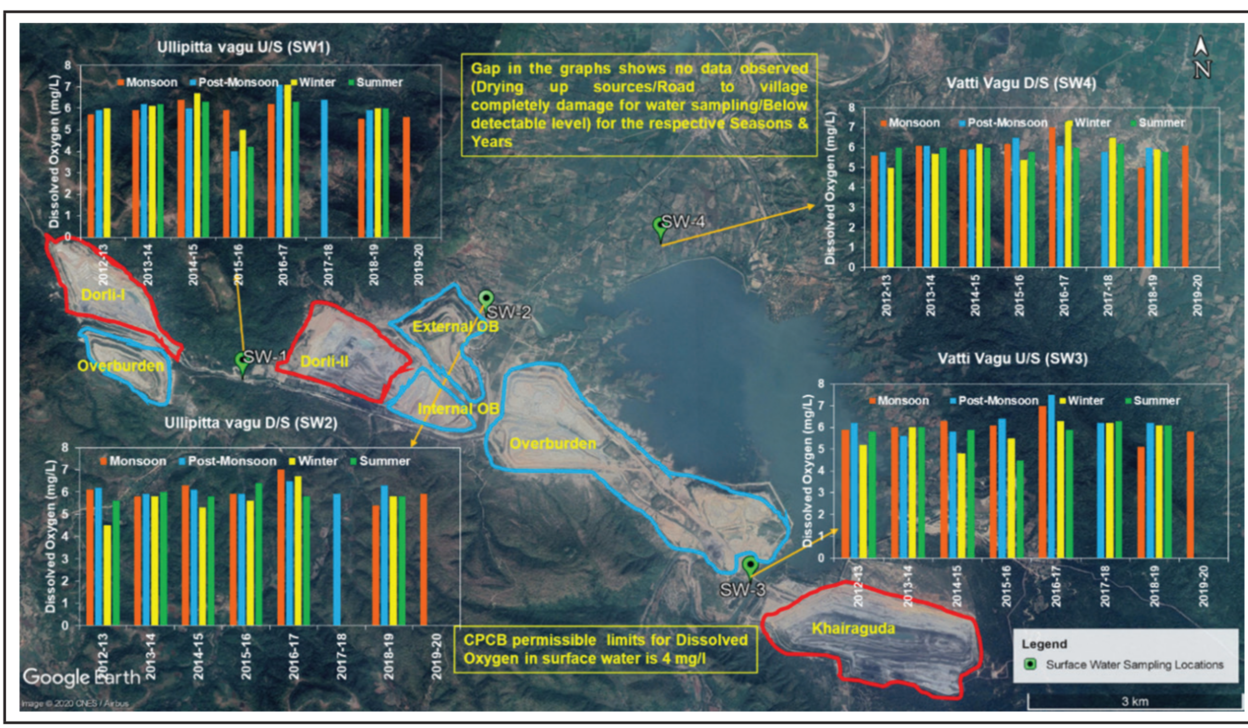

Figure 7: Seasonal variations in Dissolved Oxygen (mg/L) of surface water in Dorli OC-I, OC-II and Khairagura OCMs

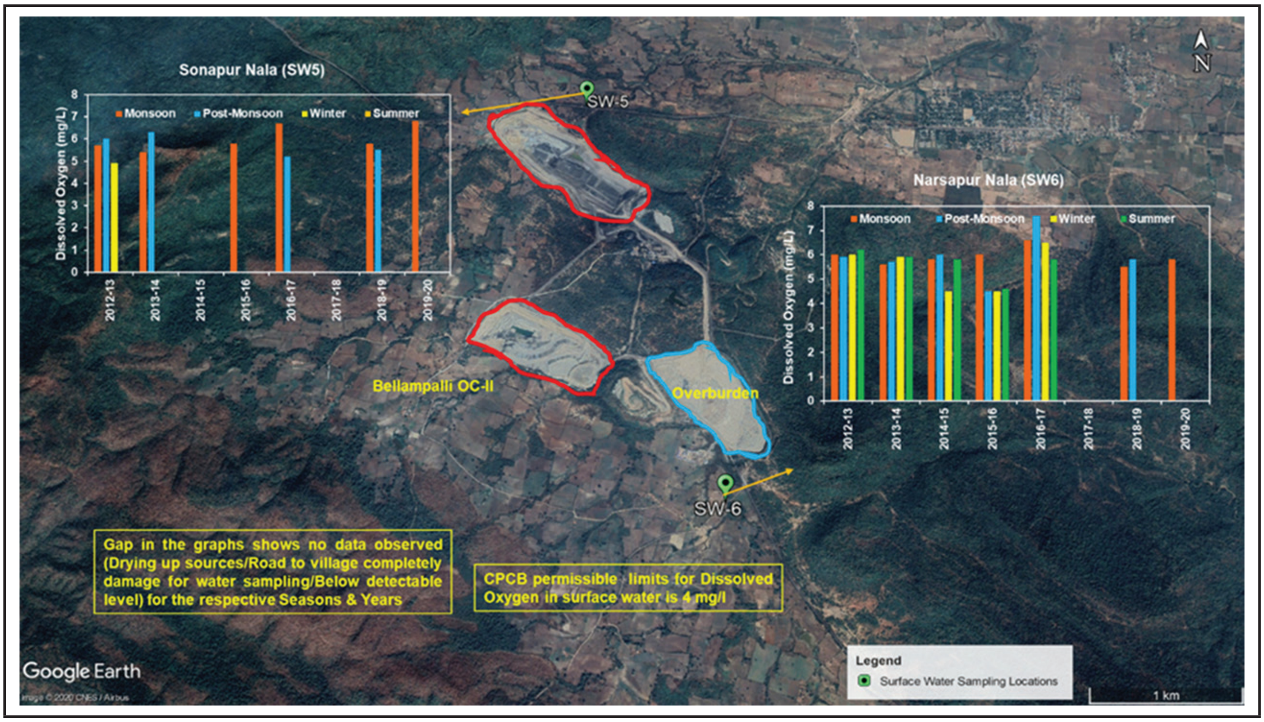

Figure 8: Seasonal variations in Dissolved Oxygen (mg/L) of surface water in Bellampalli OC-II

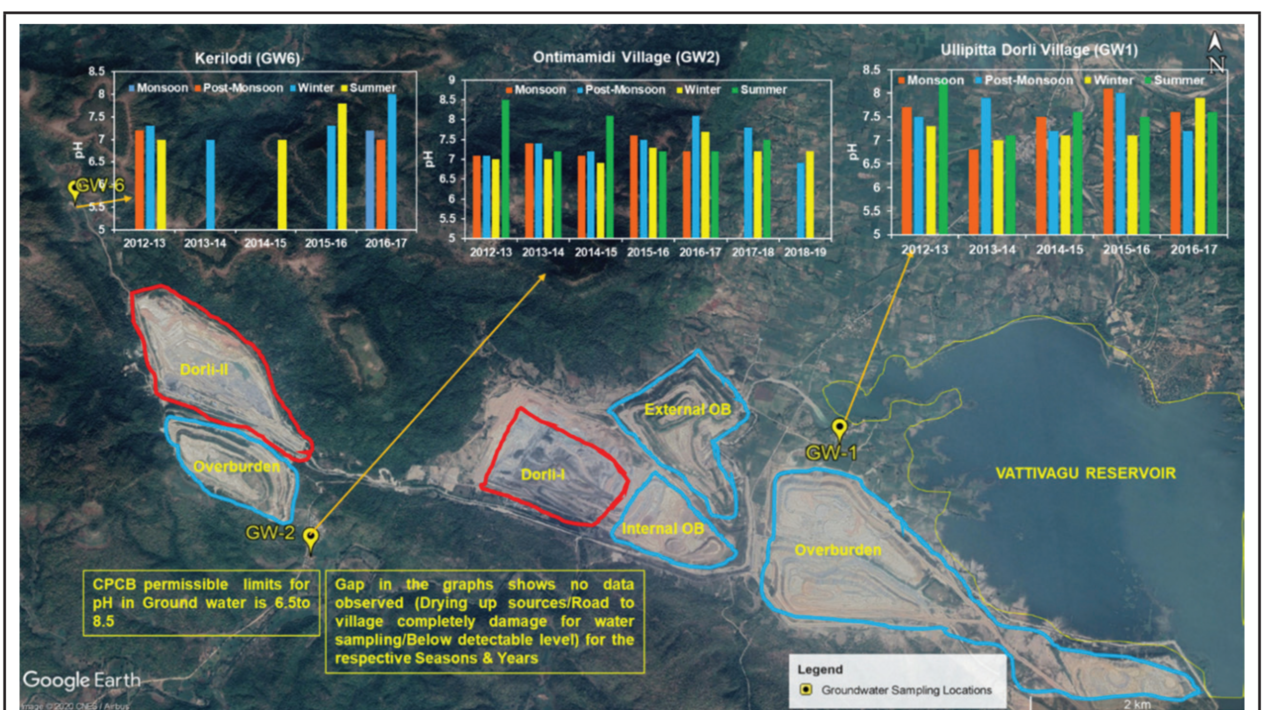

Figure 9: Seasonal variations in pH of ground water around Dorli OC-I, OC-II and Khairagura OCMs

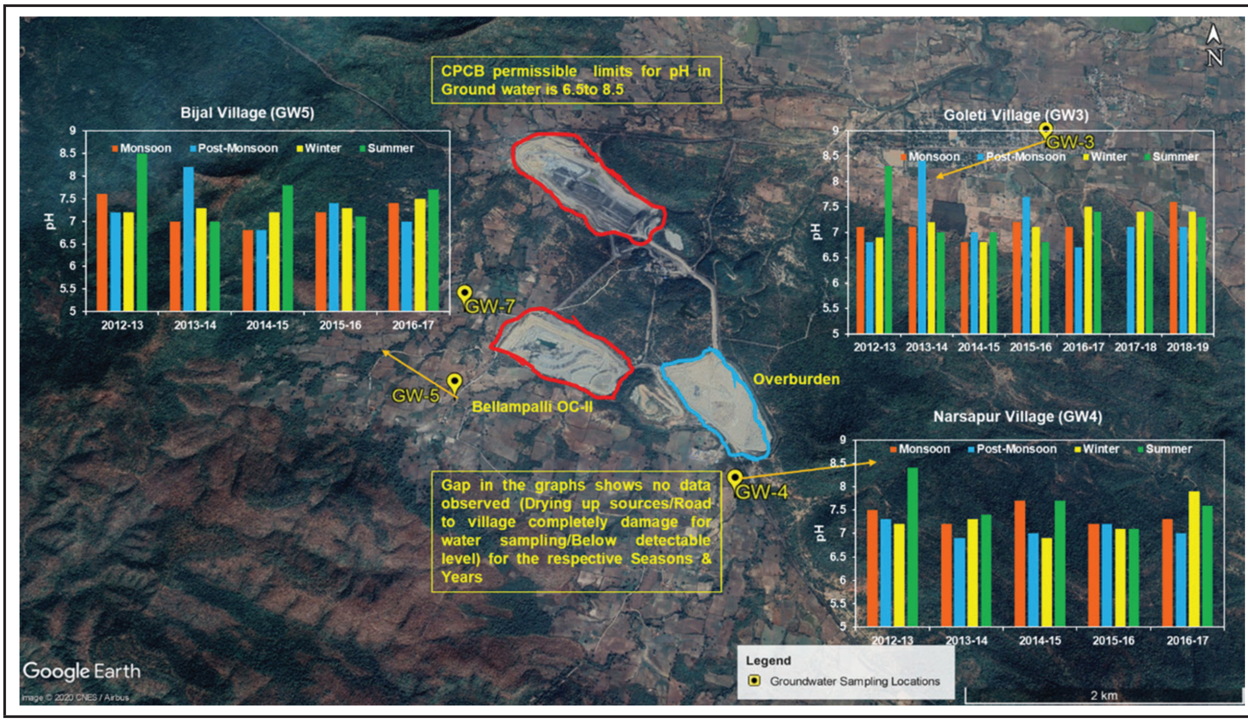

Figure 10: Seasonal variations in pH of ground water around Bellampalli OC-II

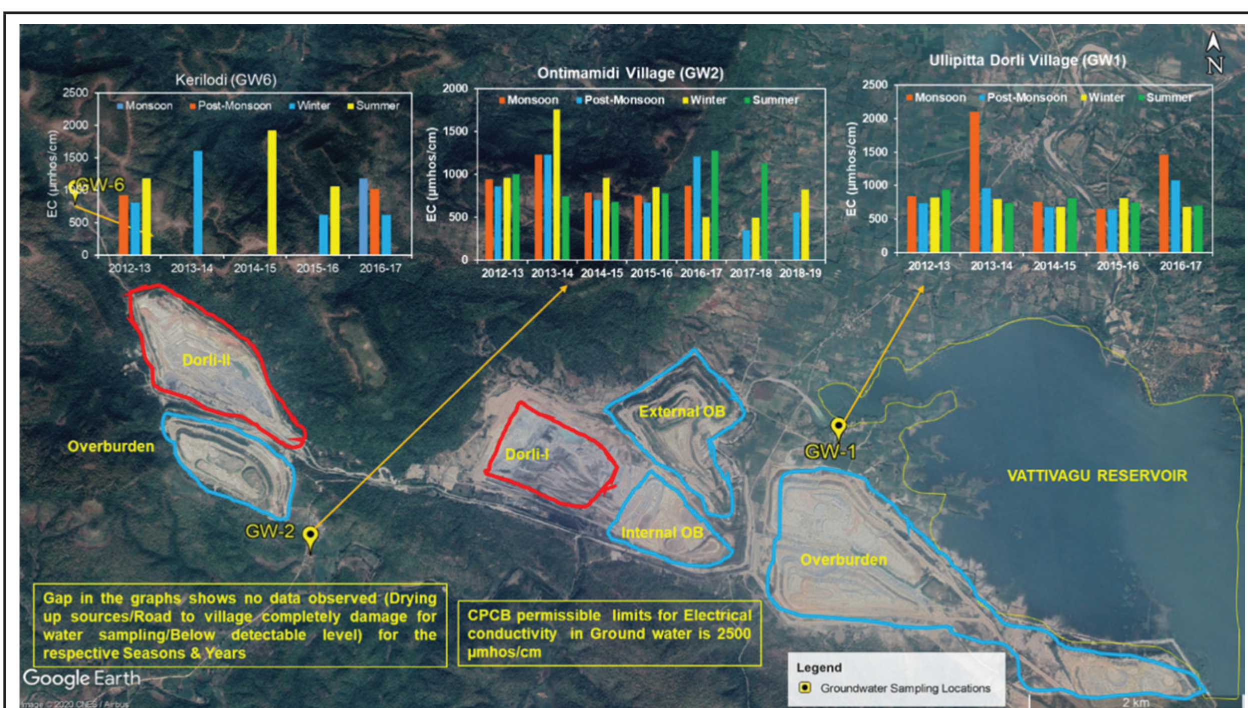

Figure 11: Seasonal variations in Electrical Conductivity (µmhos/cm) of ground water around Dorli OC-I, OC-II and Khairagura OCMs

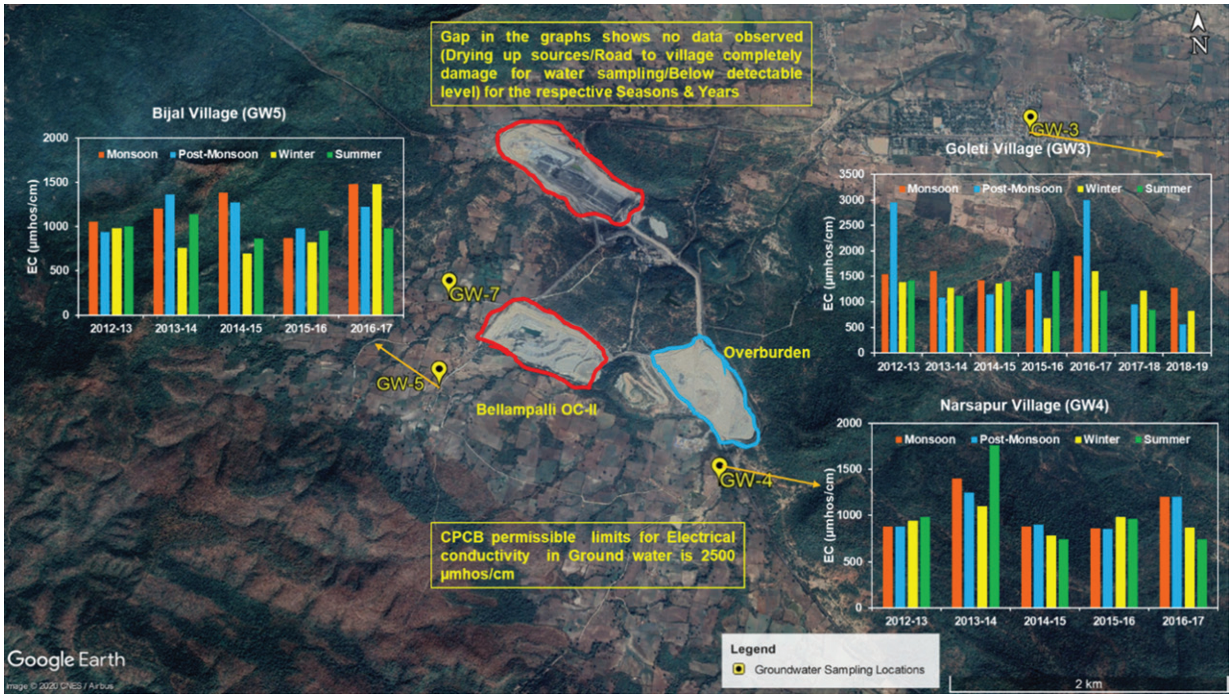

Figure 12: Seasonal variations in Electrical Conductivity (µmhos/cm) of ground water around Bellampalli OC-II

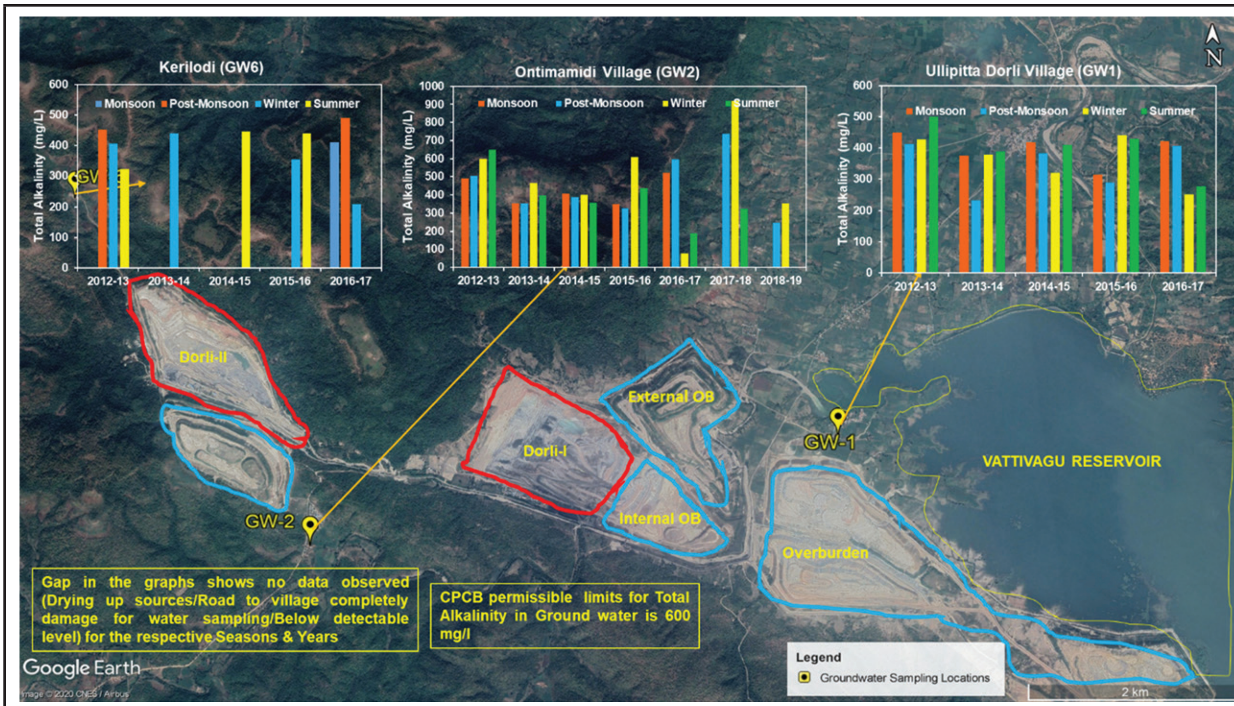

Figure 13: Seasonal variations in Total Alkalinity (mg/L) of ground water in Dorli OC-I, OC-II and Khairagura OCMs

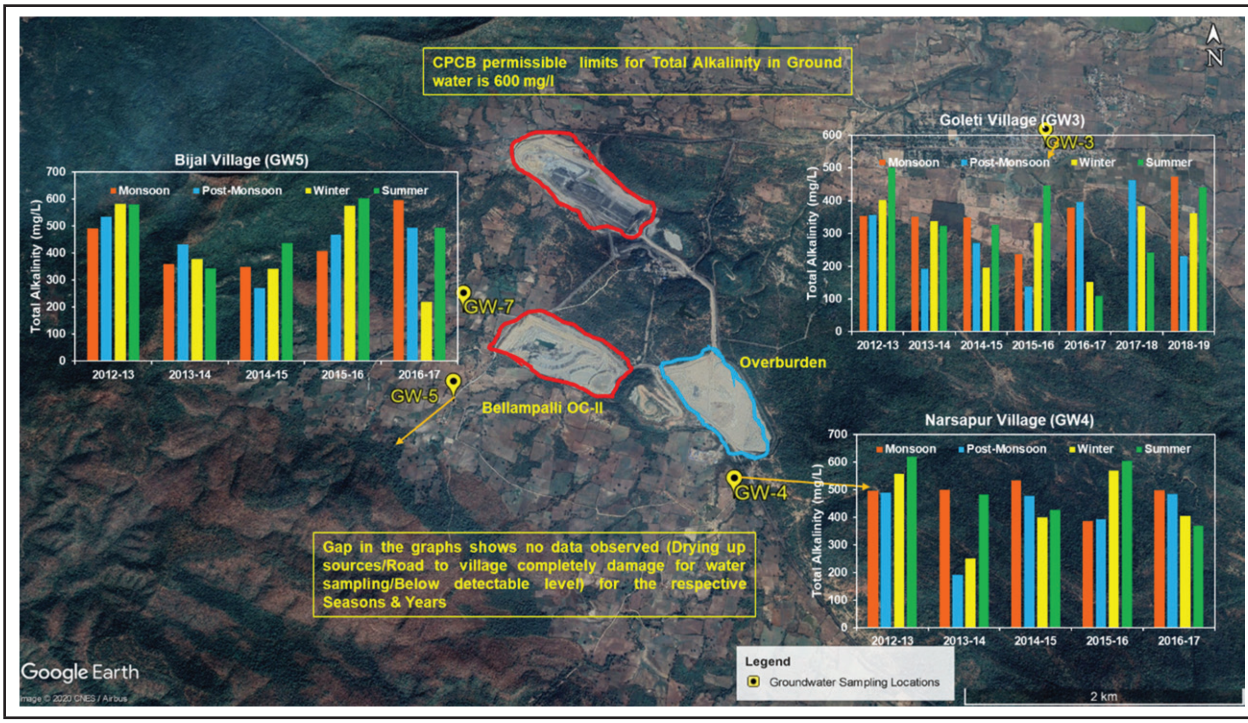

Figure 14: Seasonal variations in Total Alkalinity (mg/L) of ground water in Bellampalli OC-II

The pH and EC values were found to be well within the CPCB / BIS limits (Figures 3 – 6; BIS, 2004). In the case of pH, site SW4 (in the vicinity of Dorli II OCM) exhibited higher pH values compared to other sites in the summer season, while SW3 showed higher EC values in the Post-monsoon season. Overall, the values for DO exceed the CPCB limit during all four seasons as shown in Figures 7 and 8.

The monitoring locations from where ground water samples are drawn are shown in figures 9-14. The seasonal pH and EC values exceed the pre-mining values over all the seasons and years as shown in Figures 9-14; however, the values are within the prescribed the CPCB limits (BIS, 2004). Similar trends are observed with respect to Total Alkalinity (mg/L) concentrations. Overall trends show that apart from specific occurrences, all the major water quality parameters in the study area are within the permissible limits.

4.2. Annual trends in the water quality

The annual trends in the water quality (Surface Water and Ground Water) in the study area are discussed in this section and depicted in Figures 15-20.

The annual trends in the pH show very less variations over the years (Figures 15a and 15b, 16a and 16b and Figures 17a and 17b). The pH values are within the range of 7.7 to 8.2, which is well within the permissible limit of 8.5. While the EC data collected from the surface water samples show some variations, all the values are within the prescribed limits (Figures 15c,15d, 16c, 16d and 17c ,17d). As shown in Figures 15e and 15f, Figures 16e and 16f, and Figures 17e and 17f, the DO levels generally ranged between 5-6 mg/L in comparison to CPCB standard of 4 mg/L. These DO values (5-6 mg/L) indicate optimal level of aeration in the surface water.

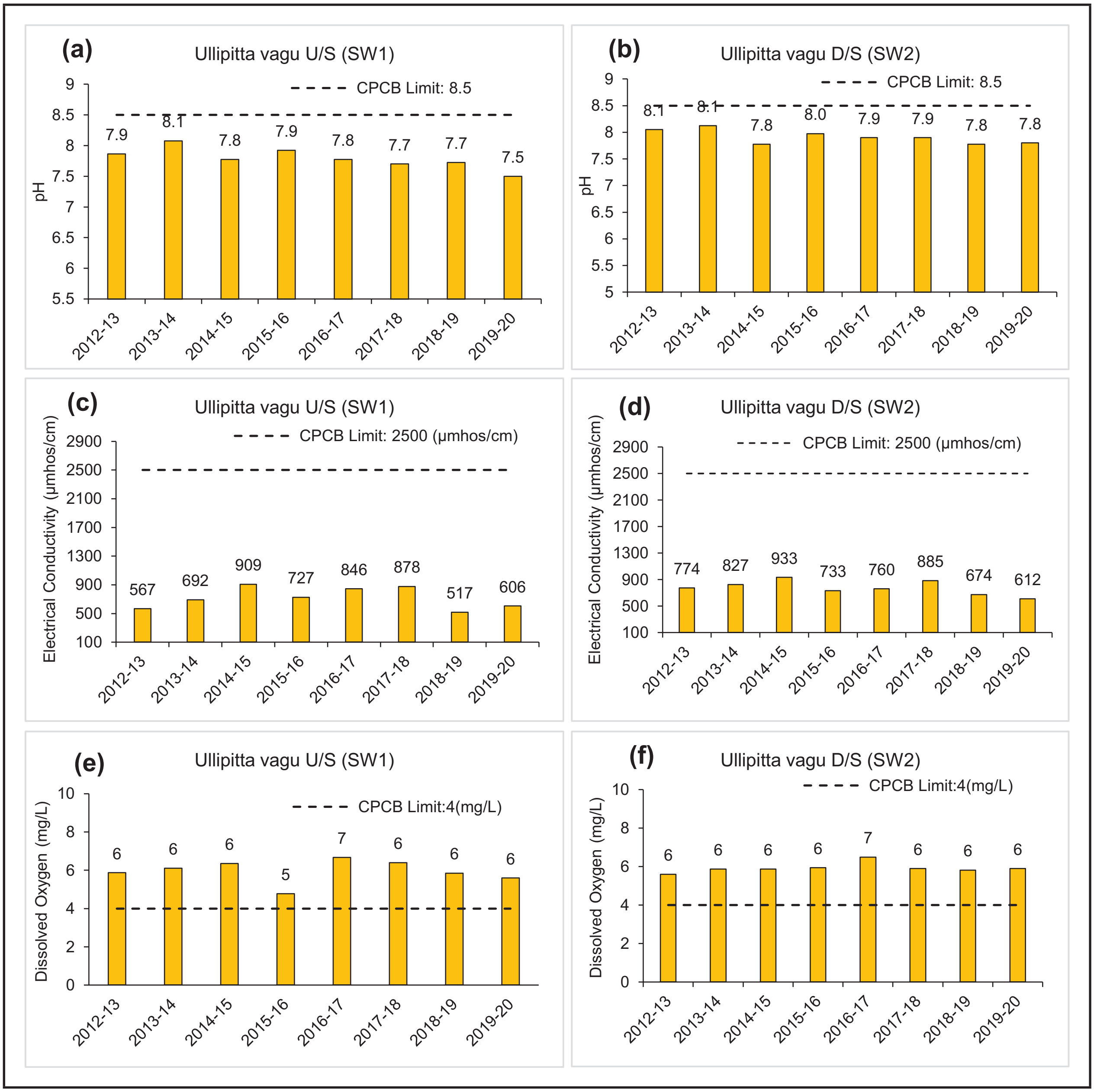

Figure 15: Annual trends of pH, EC and DO at sampling locations upstream (SW1) and downstream of Ullipitta Vattivagu (SW2).

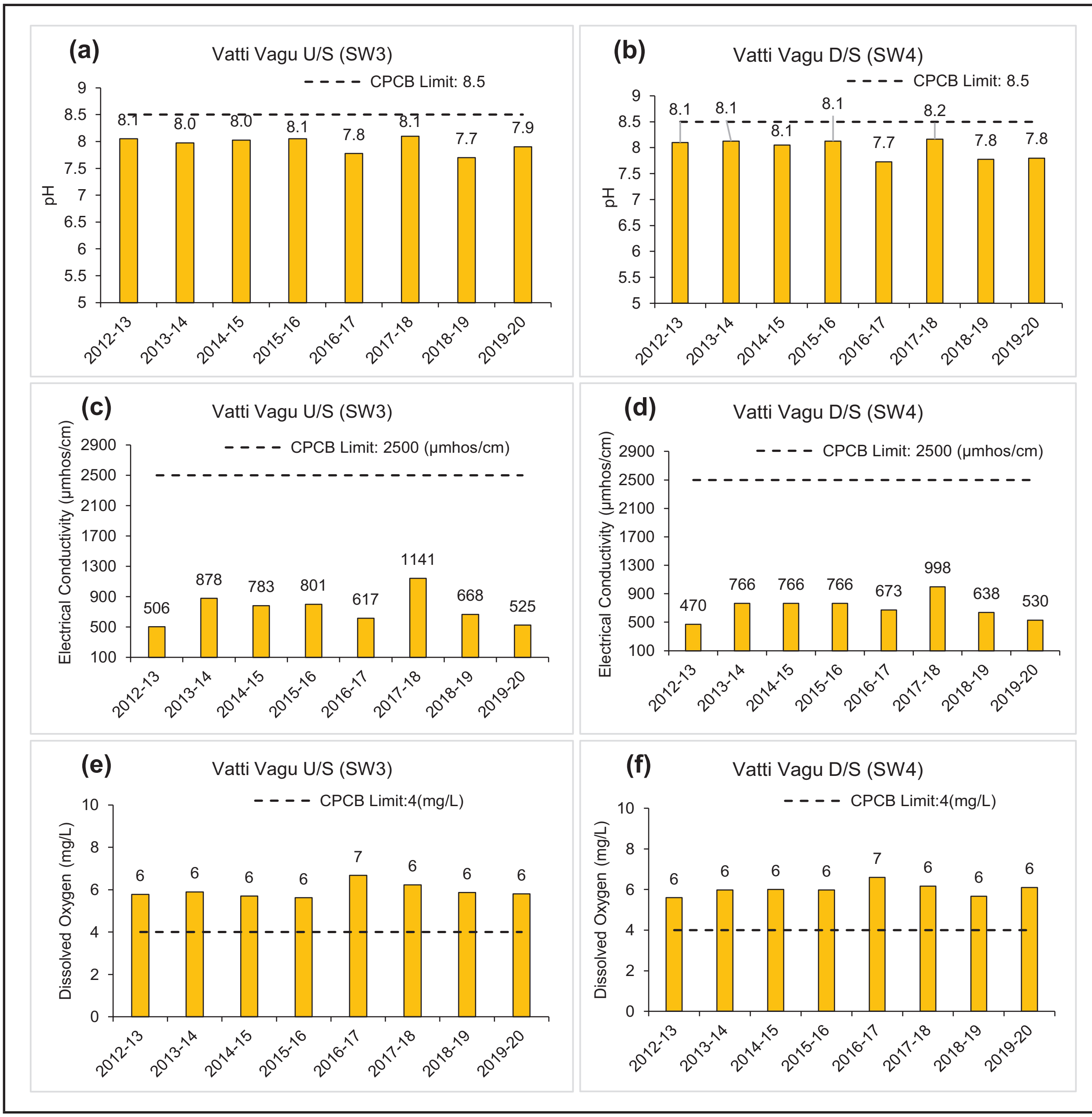

Figure 16: Annual trends of pH, EC and DO at sampling locations Upstream (SW3) and downstream of Vatti Vagu (SW4).

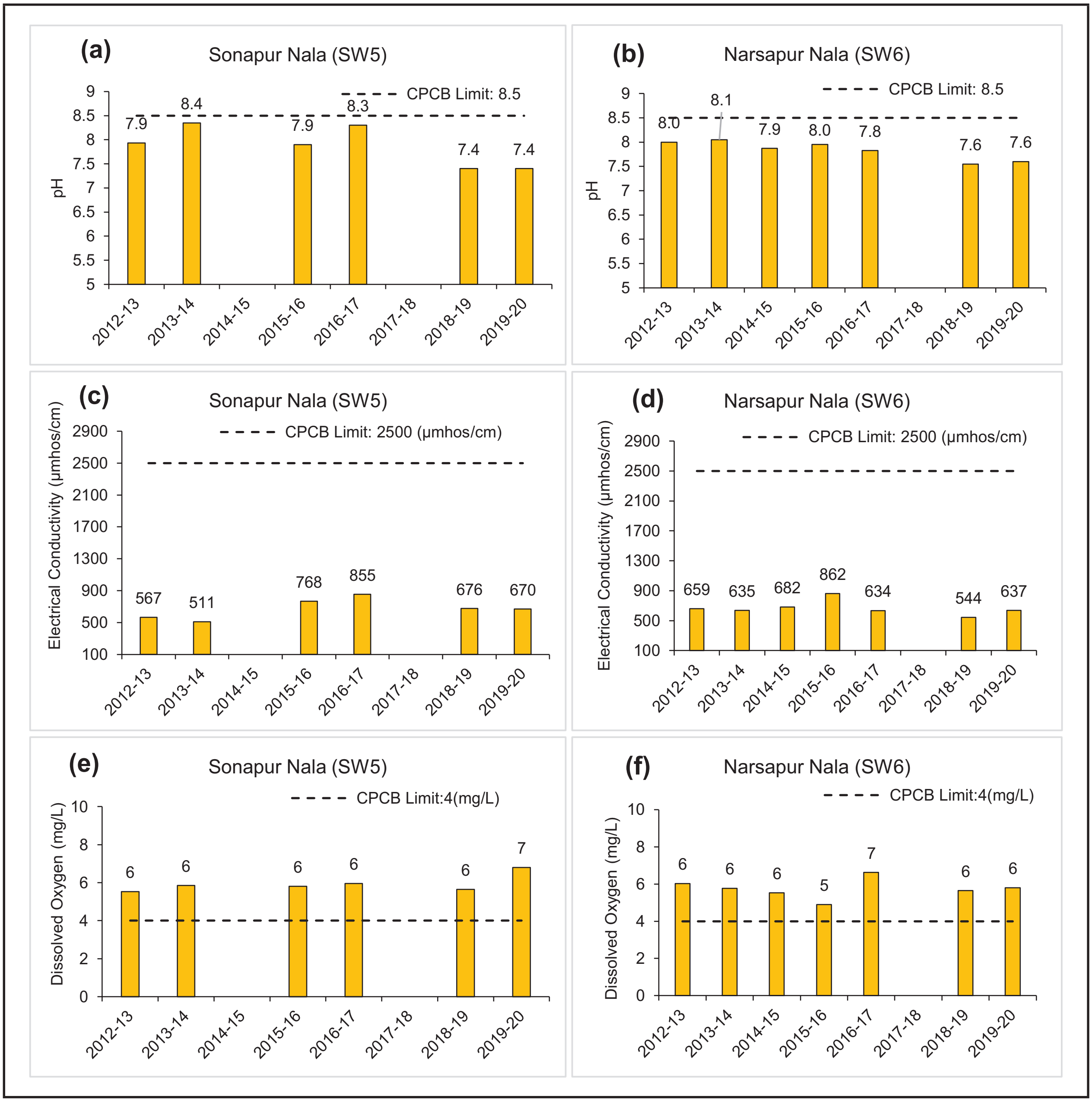

Figure 17: Annual trends of pH, EC and DO at sampling locations Sonapur nala (SW5) and Narsapur nala (SW6)

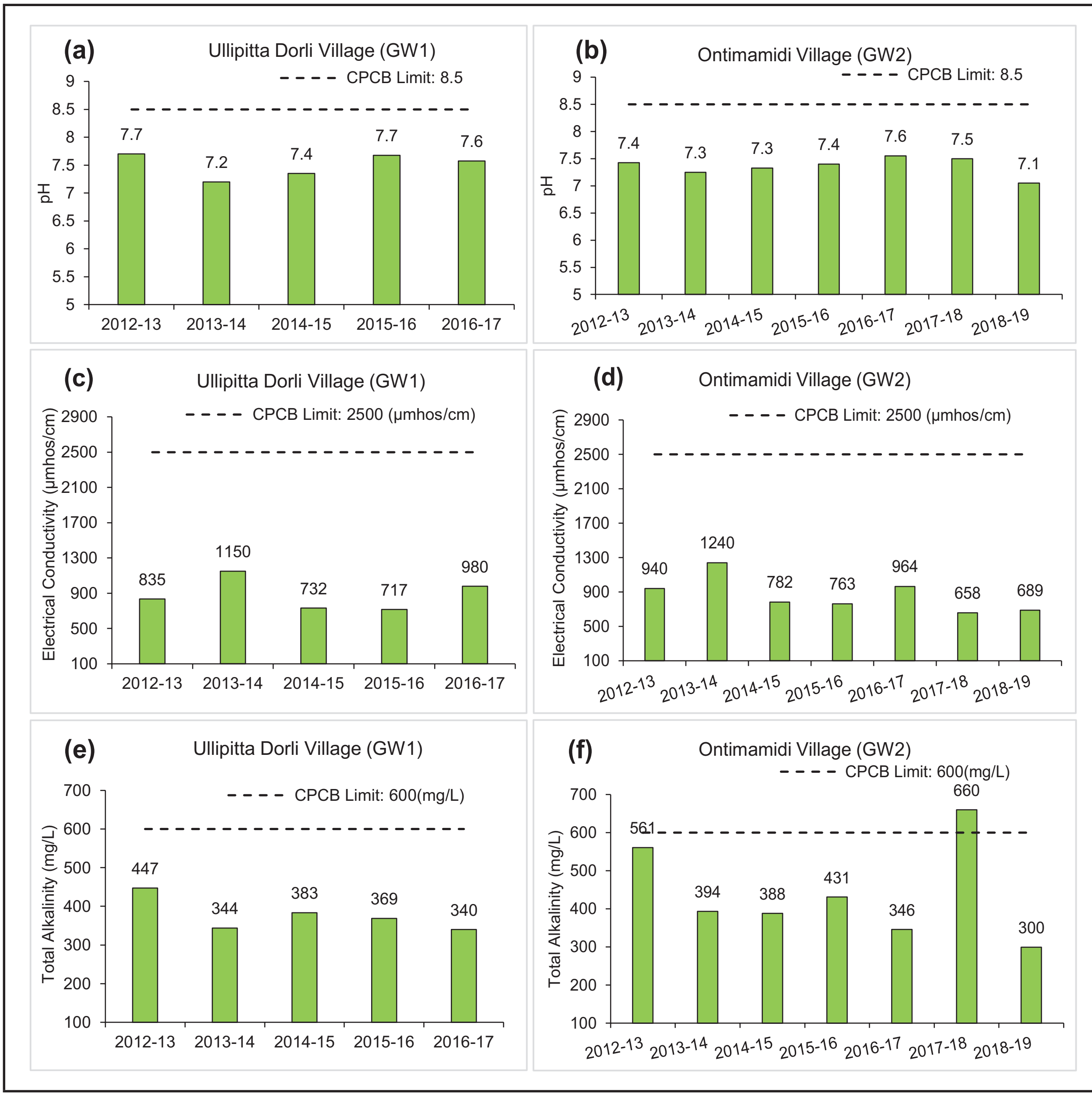

Figure 18: Annual trends of pH, EC and Total alkalinity of groundwater samples at locations Ulipitta Dorli village (GW1) and Ontimamidi village (GW2)

In the case of groundwater samples, the pH of the samples at all sites are comparatively consistent and closer to neutral reflecting the absence of contamination (Figures 18a and 18b, Figures 19a and 19b and Figures 20a and 20b). The total alkalinity (mg/L) which determines the dissolution characteristics for the groundwater was consistently high over the years (albeit within the permissible limit of 600 mg/L) reflecting a high probability for the presence of ions in dissolved state in the groundwater due to weathering or seepage (Figures 18e and 18f, Figures 19e and 19f, and Figures 20e and 20f). Except in the case of GW3 and GW6 samples, the average EC values of the ground water in all other locations (Figures 18c and 18d, 19c and 19d) is generally around 1000 μmohs/cm. While the average EC values in the case of GW3 and GW6 reach a peak of 1700 μmohs/cm in certain years (2012-13 and 2016-17 in the case of GW3, 2014-15 in case of GW6), all EC values of the ground water in the study area are within the norm of 2500 μmohs/cm. While there are annual variations in the ground water quality even at the same location, the reason for these variations can be established through a more detailed study based on more frequent sample collection and analysis.

Figure 19: Annual trends of pH, EC and Total alkalinity of groundwater samples at locations Goleti village (GW3) and Narsapur village (GW4)

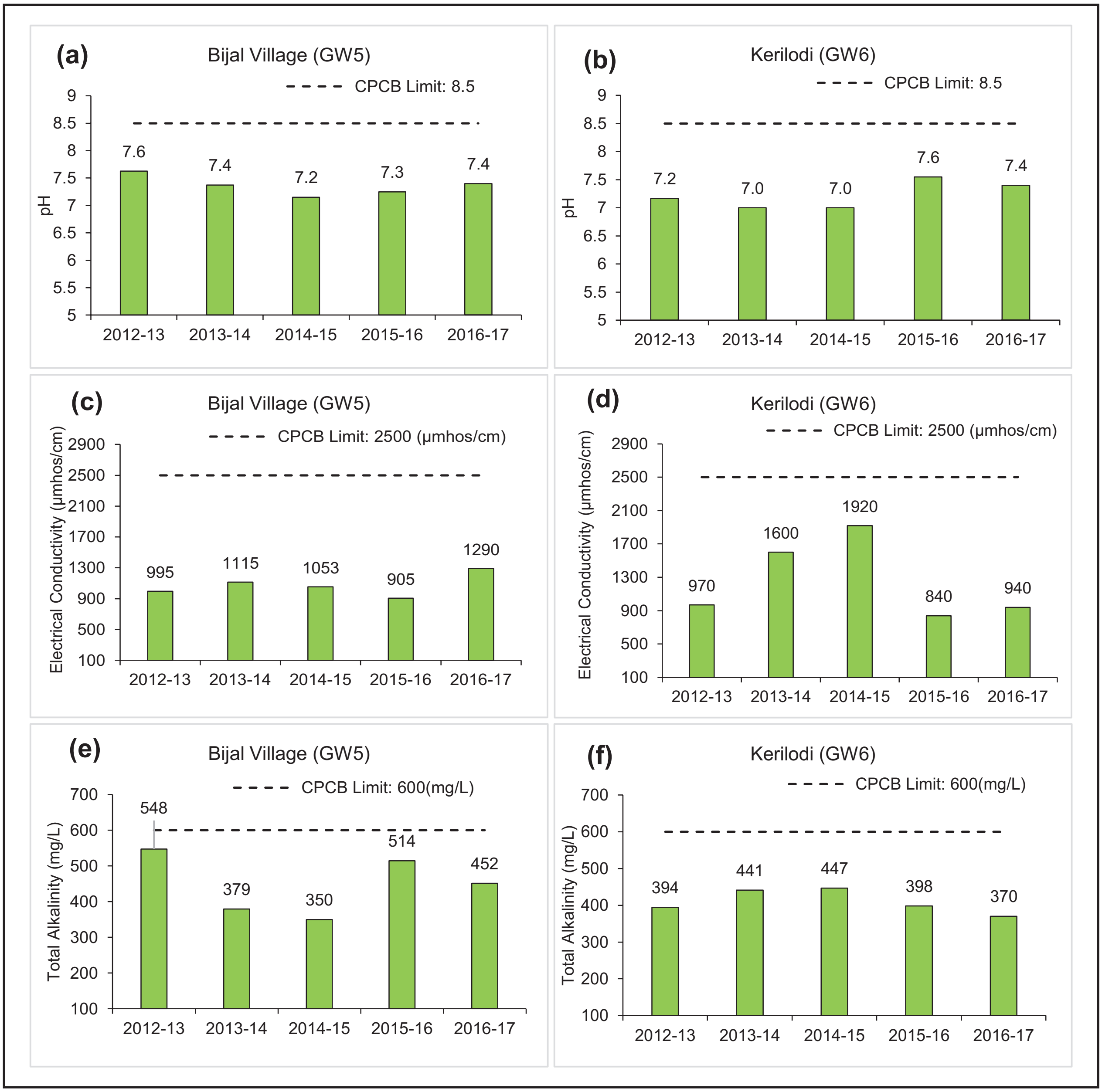

Figure 20: Annual trends in the pH, EC and Total alkalinity of groundwater samples at locations Bijal village (GW5) and Kerilodi village (GW6)

As shown in Table 2, Dorli I OCM recorded an all-time record of 22 Mm3 in Overburden (OB) removal during FY 2017-18. While this could have potentially increased the concentration of solids in surface water and therefore the EC values of SW2 in FY 2017-18, there has been only a slight increase in EC values in that year compared to earlier years (Figure 15d). This is indicative of the good management practices followed by SCCL in order to maintain a good water quality. The EC values of surface water and groundwater before and after resumption of mining activities in Bellampalli II OCM can be compared in Figures 17c and d and 20c and d, respectively. As shown in these figures, there has been no significant change in the EC values from

FY 2016- 17 onwards compared to the values recorded earlier. In all cases, the EC values of the surface water and ground water as reported by SCCL are within permissible levels. This again indicates good managerial practice.

The water quality data presented in this study has also been used to classify the surface water as per the best-use classes specified by the Central Pollution Control Board (CPCB). This analysis indicates that the surface water around the OCMs in the Dorli -Bellampalli coalfield is suitable for Class C use (drinking water) after suitable tertiary treatment. However, this water is also fit for Class D use (propagation of wildlife and fisheries) and Class E use (irrigation) without further treatment. As mandated by Section 20A of the MMDR Act (1957), there is a good potential for exploring more uses for pit lakes to assess their utility to the local communities as required since no inter-disciplinary studies (combining science, technology, and social science) have been carried out to assess the current and upcoming pit lakes in terms of their utility to the surrounding communities with an integrated approach. Therefore, there is a need to address these vital gaps in our knowledge of coal mine ecosystems post mine closure. Based on the initiative of the Ministry of Coal (MoC) for providing sustainable coal mining solutions by creating a sustainable development cell on December 15, 2019, it would be useful to explore the impact of mining on the water environment in two ways:

1. By assessing the long-term datasets for significant spatial and temporal variations in the datasets for detecting any crucial changes to the water environment

2. By providing innovative solutions for the use of constructed ecosystems such as pit lakes to manage the surface water resources of the region efficiently.

5. Air Environment

In accordance with the terms and conditions of the Environmental Clearance granted by MoEF&CC to various coal mines, SCCL has been filing half-yearly compliance statements which include air pollution monitoring data at pre-determined locations in the Core Zone (CZ) and Buffer Zone (BZ) of the four Opencast Coal Mines (OCMs) in the Dorli-Bellampalli coalfield (e.g., SCCL, 2019a; 2019b; 2019c; 2019d; 2019e; 2019f; 2019g; 2019h; 2019i; 2019j). In this section, analysis of the data (related to criteria pollutants – PM_{10}, $PM_{2.5}$, and SO_2) extracted from these monitoring reports submitted over a seven-year period is presented along with correlations with production levels from these four OCMs wherever applicable.

5.1. Ambient air concentrations of airborne pollutants in and around Dorli II OCM

The daily, seasonal, and annual variations in the PM_{10} concentrations between June 2012 and September 2019 in the core zone and buffer zone of Dorli II OCM are presented in Figures 21 (a), (b) and (c).

As shown in figure 21 (a), the daily variations in PM10 concentrations in the core zone and buffer zone of Dorli OC-II are generally lower than the standards prescribed for the core zone (250 $\mu g/m^3$) and buffer zone (100 $\mu g/m^3$). The PM_{10} concentrations reduce gradually after mining operation cease in Dorli OC-II in March, 2017. (SCCL, 2017)

The seasonal variations of PM_{10} concentration in the core and buffer zones of Dorli OC-II are shown in Figure 21 (b). As expected, the PM_{10} concentrations were high during the summer

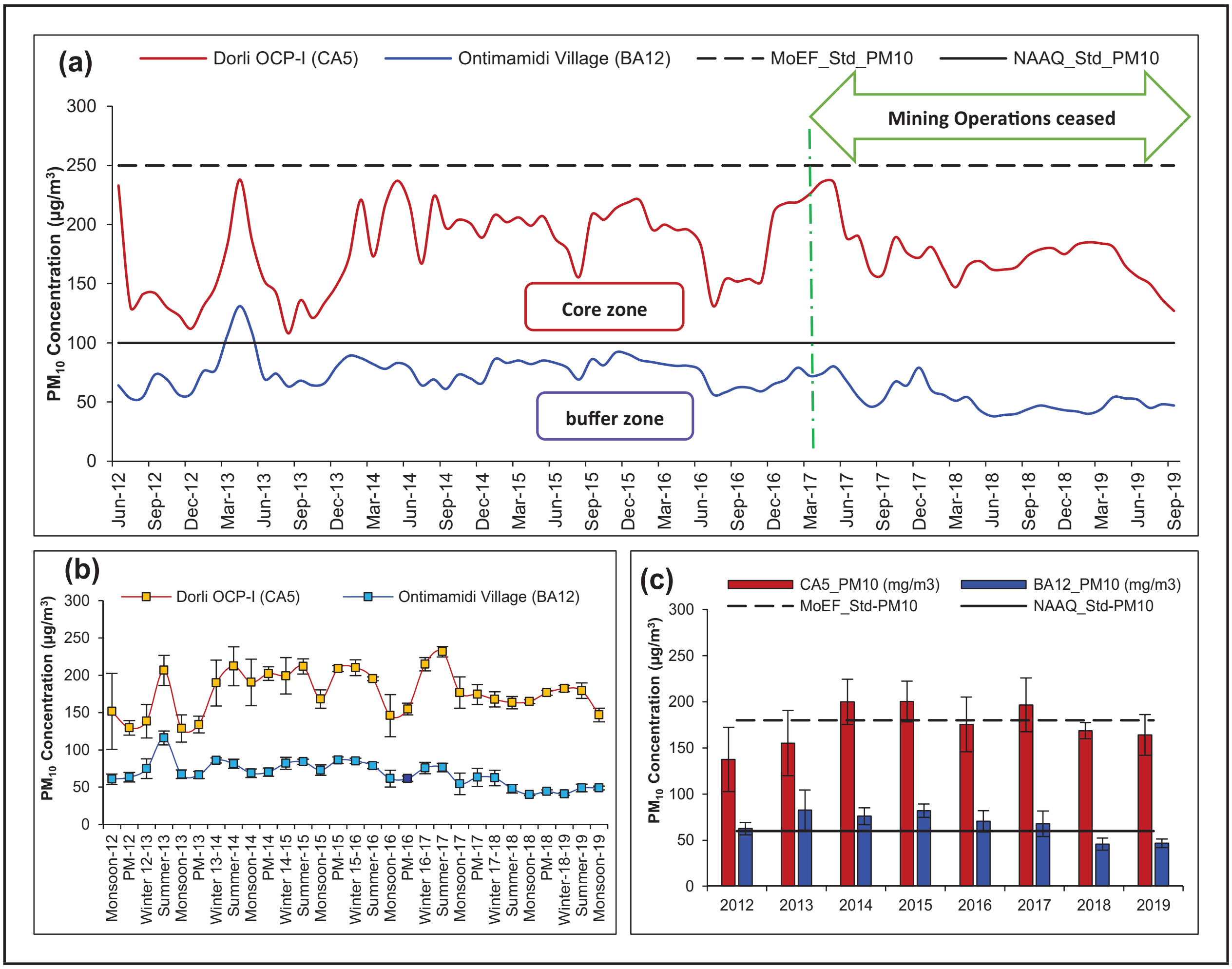

Figure 21: (a) Daily (b) seasonal average and (c) annual average concentrations of PM_{10} in the core and buffer zone of Dorli II OCM (values in µg/m³, mean±standard deviation)

and winter months. Specifically, the average PM_{10} concentration in the core zone during the winter season of the year 2016-17 was 215 µg/m³ while it reached a peak of 232 µg/m³ in summer of 2017 as shown in Figure 21 (b).

As shown in Figure 21(b), the PM10 concentrations in the buffer zone of Doli II OCM rose to a high of 76 µg/m³ during the winter of 2016-17 and the summer of 2017. Once mining operations ceased in this mine at the end of March 2017, the PM10 concentration in the buffer zone reduced to 41 µg/m³ in winter 2018-19 and 49 µg/m³ in the summer of 2019.

As shown in Figure 21 (c), the annual average PM10 concentrations in the core zone of Dorli II OCM during the years 2014, 2015, and 2017 were in the range of 200 µg/m³. These levels exceed the annual PM10 standard (180 µg/m³) for the core zone as per the Coal Mine Standards (CPCB, 2000). Similarly, the annual average PM10 concentrations during the years 2014, 2015 and 2017 (76, 82 and 68 µg/m³ respectively) in the buffer zone of Dorli II OCM also exceed the annual NAAQ standard for the buffer zone (60 µg/m³). However, once mining activities in Dorli II OCM ceased in 2017, the annual average PM10 concentrations in the core zone dropped below 180 µg/m^3 during 2018 and 2019, while the PM10 concentrations in the buffer zone during these years dropped below 50 µg/m^3. This decrease in concentrations in the core and buffer zones of Dorli OC-II is due to the cessation of mining operation in Dorli OC-II from April 2017 onwards (SCCL, 2017).

The $PM_{2.5}$ concentrations in the ambient air in the core zone and buffer zone of Dorli II OCM are shown in Figure 22 (a, b and c). While the NAAQ Standards for ambient air $PM_{2.5}$ concentrations (60 µg/m^3 limit for daily average and 40 µg/m^3 for annual average) are applicable in the buffer zone of the coal mines, there are no standards for $PM_{2.5}$ concentrations in the core zone of coal mines (CPCB, 2009). While the Directorate General of Mines Safety (DGMS) has prescribed standards for respirable dust concentrations in a coal mine to protect the health of persons employed in the coal mines, there is a need for CPCB to notify standards for $PM_{2.5}$ concentrations (which are known to cause health impacts at elevated concentrations) in the core zone of coal mines, since the residential colonies (along with service providers) may be located in the mining lease area which forms part of the core zone of the coal mines (DGMS, 2017; 2018).

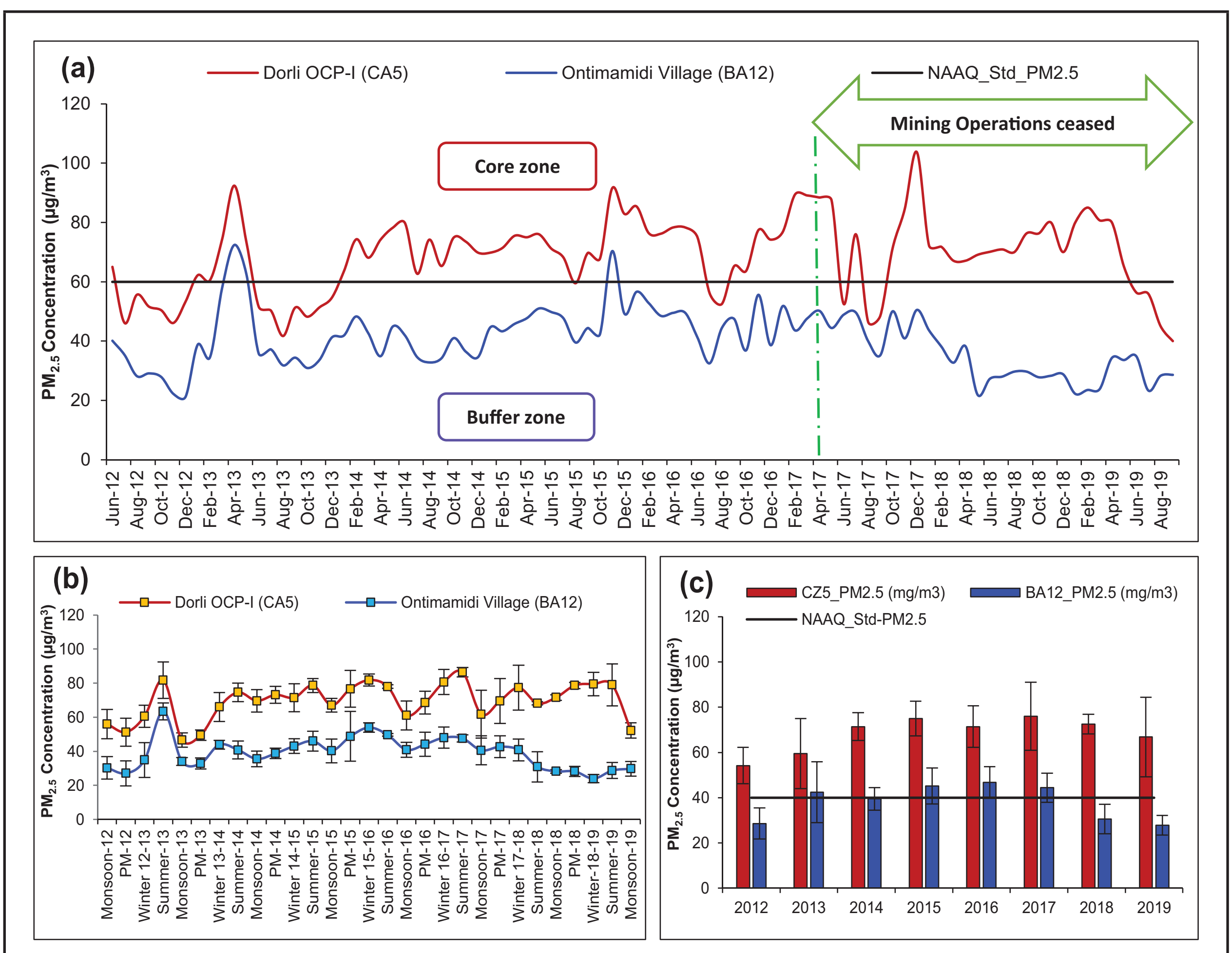

Figure 22: (a) Daily (b) seasonal average and (c) annual average concentrations of $PM_{2.5}$ in the core and buffer zone of Dorli II OCM (values in µg/m^3, mean±standard deviation)

As shown in Figure 22 (a), the $PM_{2.5}$ levels in the buffer zone of Dorli II OCM are generally compliant with the NAAQ standard (60 µg/m^3). Since mining operations in Dorli II OCM ceased in March 2017, there is a sharp fall in the $PM_{2.5}$ concentrations after the summer (March, April, and May) of 2017 as shown in Figure 22(b). As a result, the annual average $PM_{2.5}$ concentrations which exceed the annual standard in the buffer zone between 2013 and 2017 declined continuously below the standard (60 µg/m^3) in 2018 and 2019 as shown in Figure 22(c).

One point worth noting in Figures 21 and 22 is that the PM concentrations decrease at a slow pace even after the cessation of mining operations in Dorli II OCM from April 2017 onwards. This may also be due to the fact that the 90-m high OB dumps also form a major source of dust pollution. Therefore, the slopes of the OB dumps must be vegetated with suitable tree species while maintaining a dump slope which faciliatates quick vegetation growth in order to reduce ambient air pollution around the coal mines. The ambient air SO_2 concentrations in and around Dorli II OCM are shown in Figure 23 (a, b, and c). The daily and annual SO_2 concentrations in the core zone are significantly lower than the daily standard of 120 µg/m^3 and the annual standard of 80 µg/m^3 (CPCB, 2000) Both the daily and annual SO_2

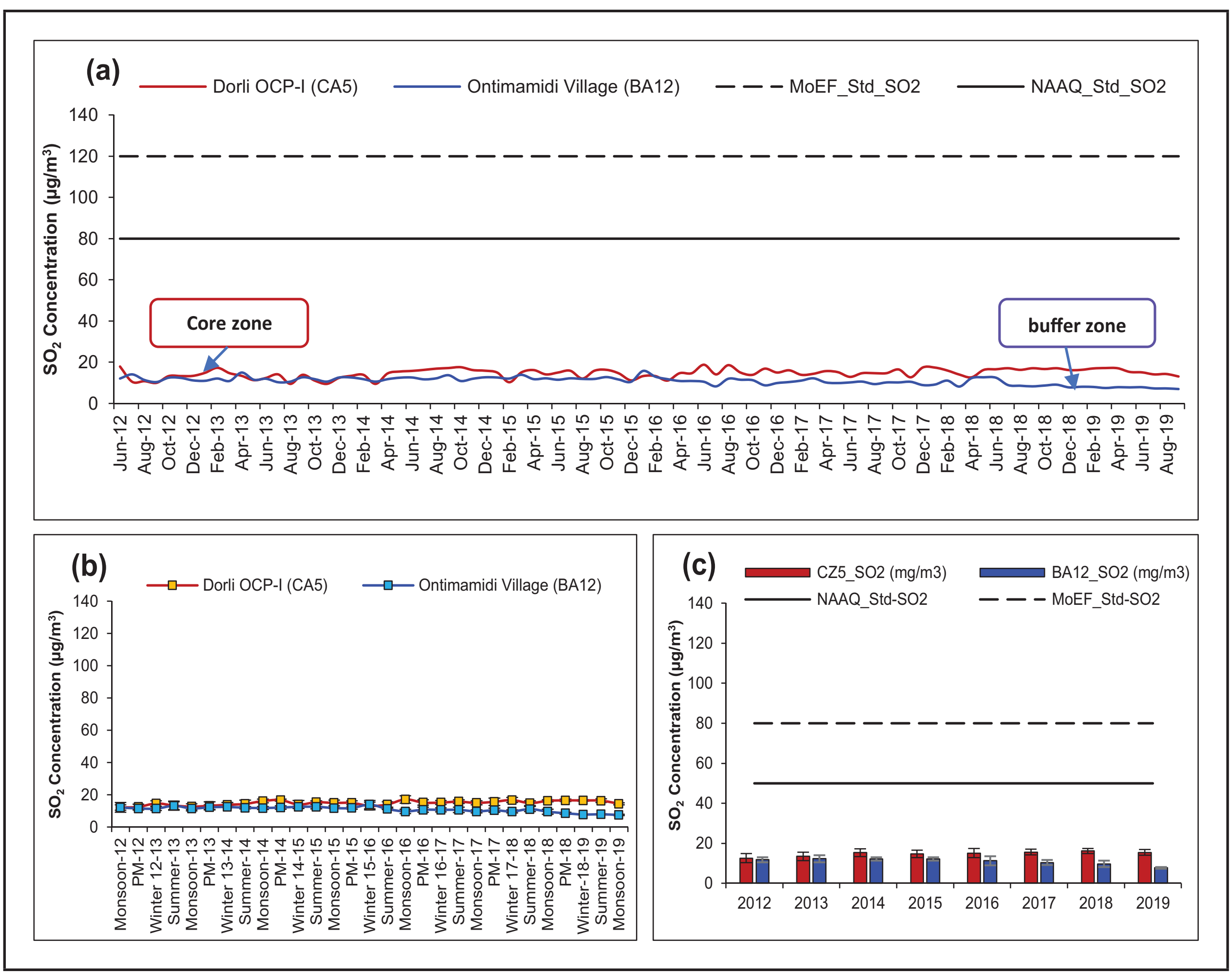

Figure 23: (a) Daily (b) seasonal average and (c) annual average concentrations of SO_2 in the core and buffer zone of Dorli II OCM (values in µg/m^3, mean±standard deviation)

concentrations in the buffer zone are also far below the corresponding NAAQ standards (80 and 50 μg/m³) as per CPCB (2009) indicating that SO_2 levels are not a major concern around coal mines.

5.2. Ambient air concentrations of airborne pollutants in Dorli-Bellampalli coalfield

The ambient air concentrations of PM_{10}, $PM_{2.5}$, and SO_2 in the buffer zones Dorli-Bellampalli Coalfield are shown in Figures 24, 25, and 26. As explained in Section 2.2 of this report, the buffer zone of a project includes an area with a radius of 10 km around the core zone (which is limited to the mining lease in the case of a mining project). Since ambient air monitoring stations in the buffer zone are generally set up in the neighbouring villages based on the wind direction in the proximity of the mine, the ambient air concentrations in the buffer zones of the four opencast coal mines in the Dorli-Bellampalli coalfield have been analysed in this section.

As shown in Figure 25, the annual $PM_{2.5}$ concentrations in the buffer zones of the OCMs in the Dorli-Bellampalli coalfield show a rising trend between FY 2013-14 and FY 2015-16 before declining gradually from FY 2016-17 onwards. This rise in $PM_{2.5}$ concentrations between FY 2013-14 and FY 2015-16 may be related to the rise in excavation quantities during this period (Figure 2). However, there is no surge in concentrations between FY 2016-17 and 2017-18 when excavation volumes increase from 48 Mm³ to 62 Mm³. No such trends are discernible in the PM_{10} levels other than a drop in PM_{10} levels in FY 20 after Dorli I OCM is also closed.

As shown in Figures 24 and 25, the PM_{10} concentrations in the buffer zones of these opencast coal mines exceed the annual standard of 60 μg/m³ during the period FY 2012–13 to FY 2017-18, while the $PM_{2.5}$ levels in these buffer zones exceed the annual standard of 40 μg/m³ during the period FY 2014–15 and FY 2017-18. The drop in PM concentrations from FY 2018-19 onwards (Figures 24 and

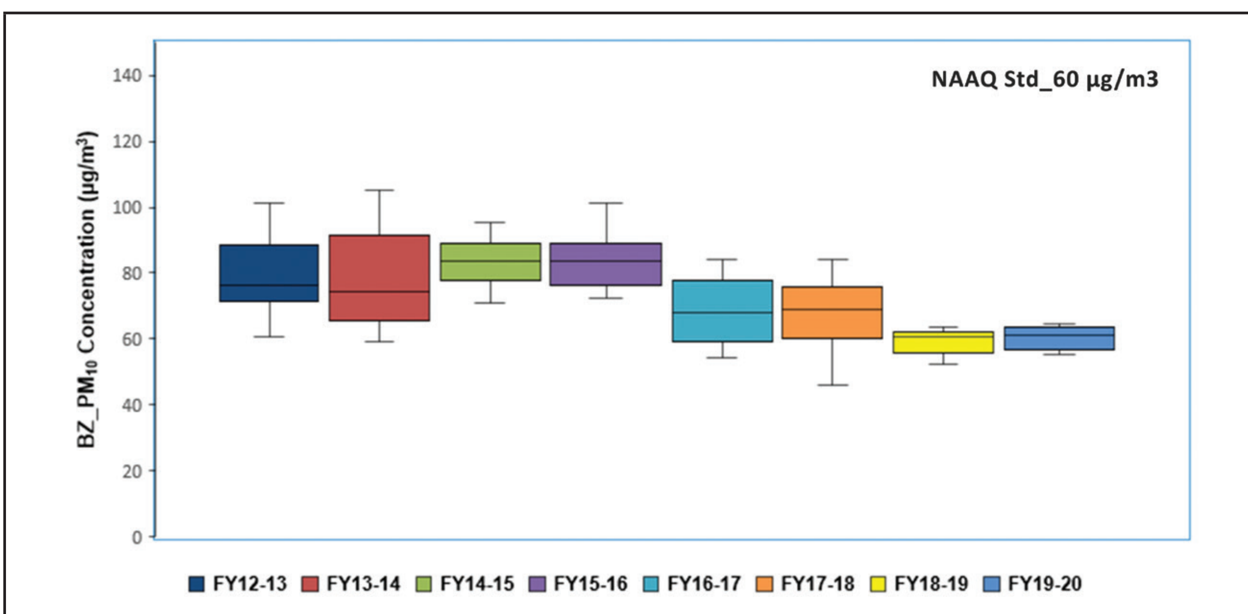

Figure 24: Annual variation of PM_{10} concentrations in the buffer zone of OCMs in the Dorli-Bellampalli coalfield

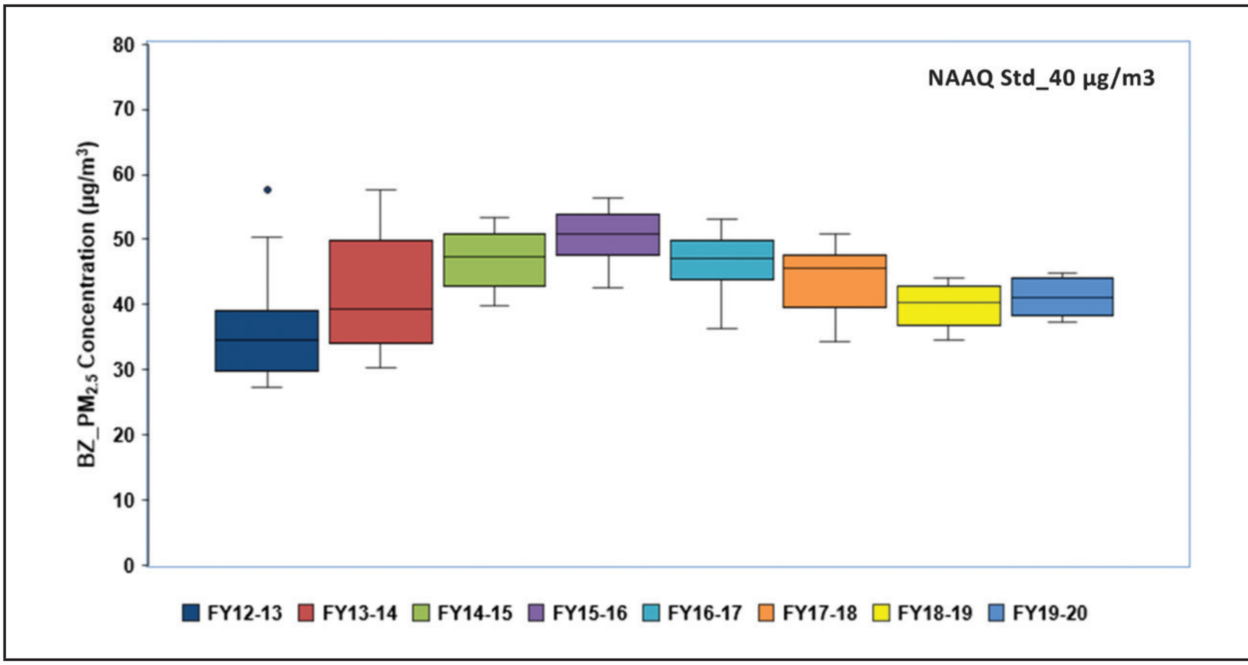

Figure 25: Annual variation of $PM_{2.5}$ concentrations in the buffer zone of OCMs in the Dorli-Bellampalli coalfield

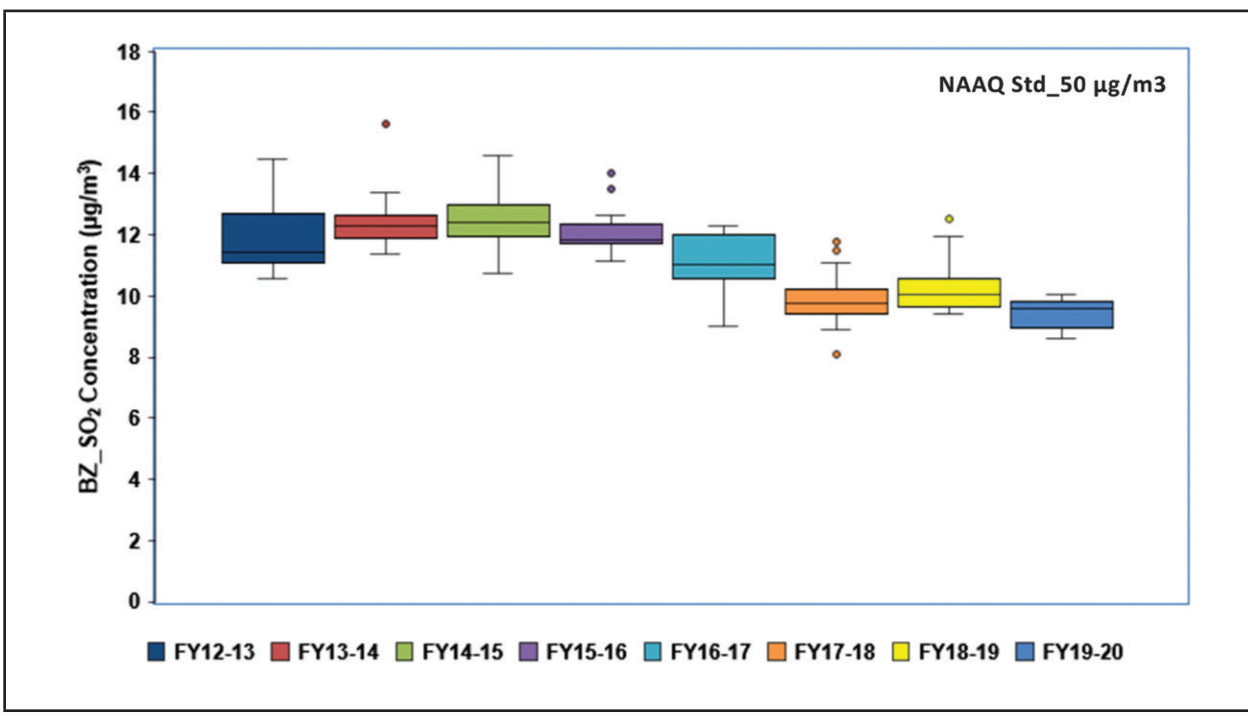

Figure 26: Annual variation of SO_2 concentrations in the buffer zone of OCMs in the Dorli-Bellampalli coalfield

25) is due to the closure of Dorli II OCM (in March 2017) and Dorli I OCM in March 2019. However, as shown in Figure 26, the annual SO_2 concentrations in the Dorli-Bellampalli coalfield are far below the standard of 50 µg/m^3 during the study period.

5.3. Spatial analysis of the ambient air concentrations in the Dorli-Bellampalli coalfield

The Inverse Distance Weighted (IDW) method is a spatial interpolation technique that has been used in conjugation with GIS software to create visually comparable choropleth maps. Spatial interpolation of known data from various geographical locations will help us to create a raster surface with estimates for all raster cells including those with unknown values. Maps prepared using IDW technique have been used for visualising air pollution data to understand the spatial distribution of pollutant concentrations (Gómez-Losada et al., 2019; Jumaah et al., 2019; Documentation QGIS2.8. Spatial Analysis Interpolation, 2020).

In this study, spatial distributions of annual average concentrations during the years 2015 and 2018 have been analysed using the IDW technique. The year 2015 was selected since one of the four coal mines (Bellampalli-II OCM) was not in operation during that year (having been temporarily stopped between November 2011 and March 2016) while the other three OCMs were in operation. On the other hand, during the

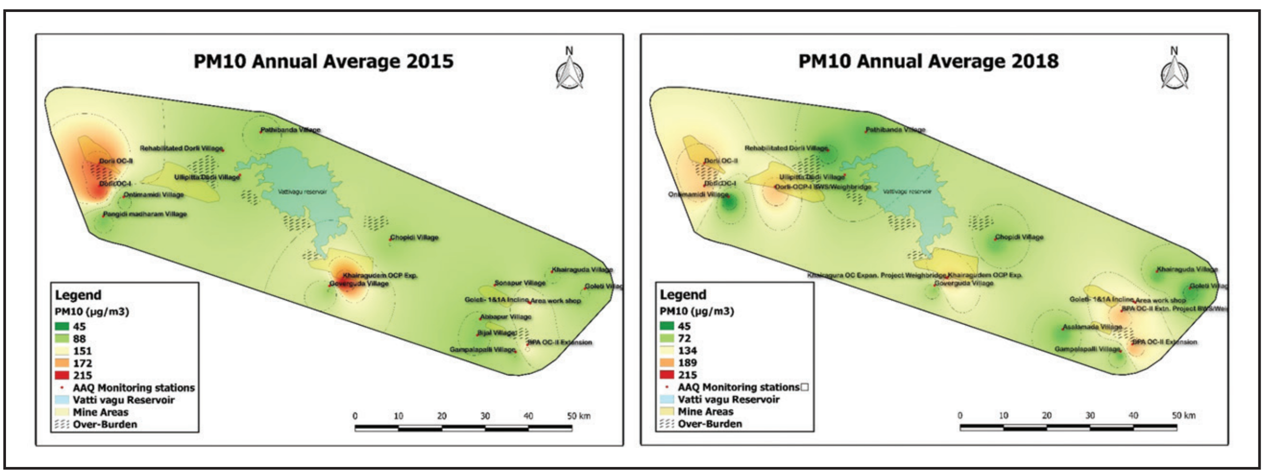

Figure 27: Spatial variation in PM_{10} concentrations before and after mine closure

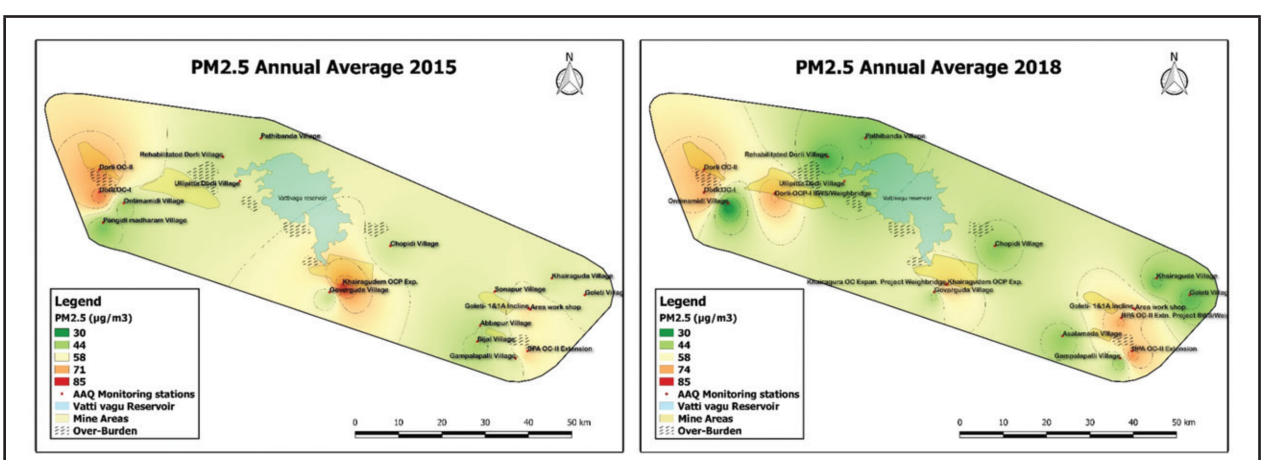

Figure 28: Spatial variation in $PM_{2.5}$ concentrations before and after mine closure

year 2018, Dorli-II OCM was not in operation (having ceased production in April 2017) while the other three OCMs (including, Bellampalli II OCM) were in the production phase. Since these two OCMs (Dorli-II and Bellampalli) are located at either end of the study area, the impact of mining operations on the air environment can be assessed by comparison of the maps created using the IDW interpolation technique. The PM_{10} and $PM_{2.5}$ concentration maps in the Dorli-Bellampalli coalfield are shown in Figures 27 (a and b) and 28 (a and b) respectively for the years 2015 and 2018. Such maps can be useful to assess the impact of air pollution on the vegetation as well as public health in future studies that will be undertaken by NIAS. Specifically, the change detection of the vegetative cover can directly indicate the impact of coal dust on the growth of vegetation and land use changes. This is an area of future research for NIAS in this and other coalfields in conjunction with our ongoing research on coal mine closure.

6. Mine closure

Pit lake systems evolved from open-cast coal mine voids have the potential to be a more cost-effective, environment-friendly and beneficial option for coal mine closure as opposed to the current mandate of backfilling the final void by re-handling the previously excavated and vegetated overburden dumps. However, it is possible to transform the final void into a pit lake water reservoir to supply water for irrigation during the post-monsoon months by implementing a scientific approach to the design and management of pit lakes. The schematic of the handling of the void final void proposed by SCCL in the approved mine closure plan for Dorli I OCM is shown in Figure 29(a). SCCL had earlier proposed to fill up with water, 128 hectares (63 percent of the mined-out area) of the de-coaled final void in Dorli I OCM, which was approved by MoEF as a part of the Environmental Clearance (EC) granted to Dorli I OCM on June 19, 2006 (SCCL, 2006a). Similarly, SCCL had proposed to fill up with water, 71 hectares (65 percent of the mined-out area) of the de-coaled final void in Dorli II OCM which was approved by MoEF as a part of the EC granted to Dorli II OCM also on June 19, 2006 (SCCL, 2006b). However, in the EC granted to Khairagura Expansion OCM on February 6, 2015, MoEF&CC has mandated that out of a total void of 542.91 hectares, the depth of the water body that will be created in the final void of 280.98 hectares (52 percent of the mined-out area) must be limited to 40 meters only (SCCL, 2015).

Subsequently, MoEF&CC revised the standard EC conditions for OCMs in August 2018 by mandating "adequate engineering interventions" to be implemented to sustain aquatic life in case the depth of the final mine void exceeds 40 m (MoEF&CC, 2018). To incorporate MoEF&CC's mandate to ensure that pit lakes are designed to sustain aquatic life, one alternative may be to fill up the pit by re-handling the already vegetated overburden up to a depth of 40 m from the surface (Figure 29(b)). However, this alternative has a number of drawbacks including a huge cost burden on SCCL while thousands of planted trees must be cut to excavate the already vegetated overburden for backfilling the 130 - 220 meters deep mine voids up to a depth of 40 m from the surface. Since neither of these current alternatives ensure the utilisation of the mined-out area for the benefit of local communities, other alternatives must be researched, developed and tested through a systematic process. The out-of-box hypothesis developed by us for further discussions and field-based research is shown in Figure 29(c). However, this innovative process must be tested through a field-based research methodology before it can be proven.

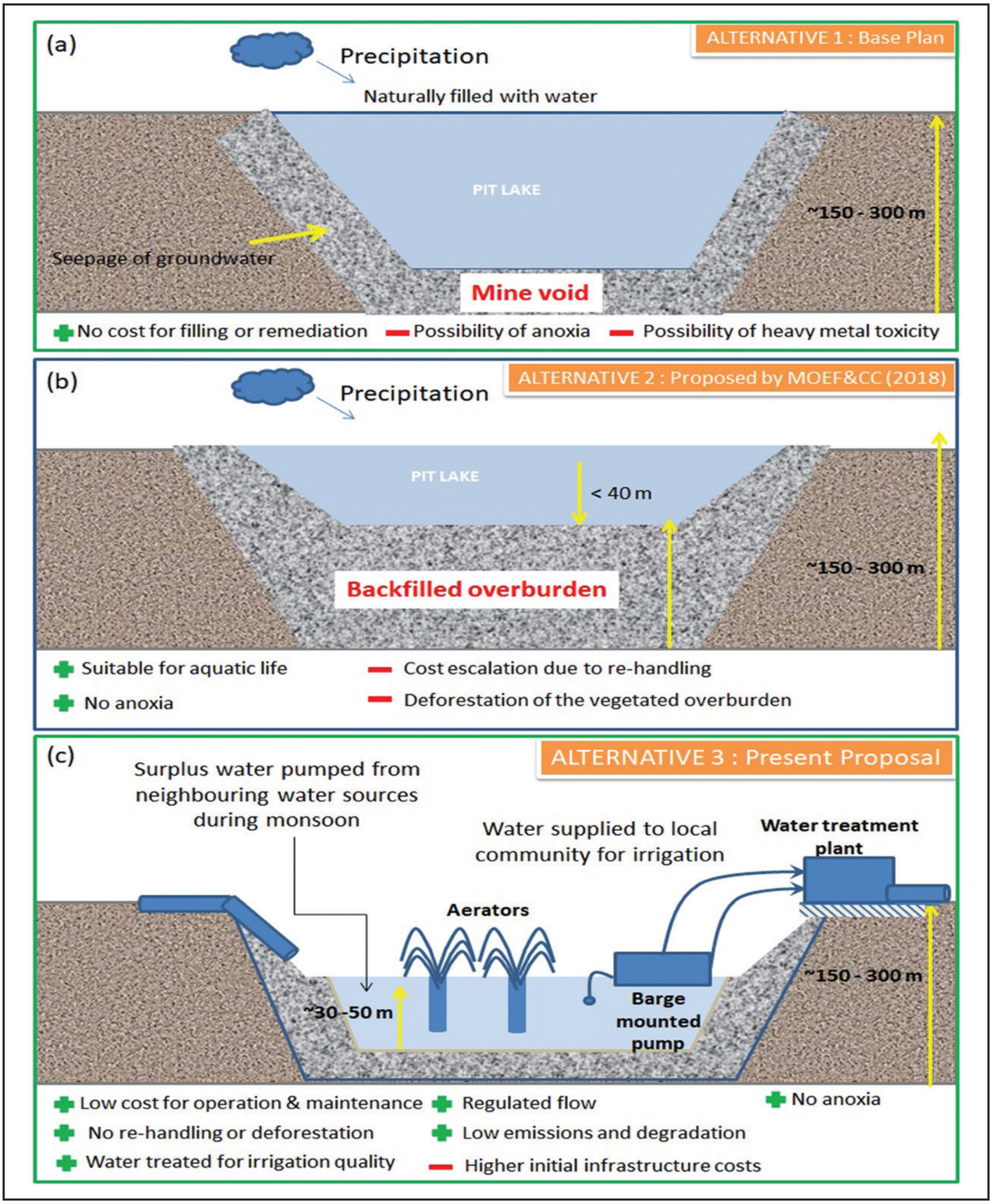

Figure 29: Alternatives for OCM Pit Lakes. Figures. 29 (a) and (b) show the Base Case and the alternative mandated by MOEFF&CC (as per the standard EC conditions for opencast coal mines), respectively. Figure. 29(c) shows one of the alternatives proposed for future research by NIAS in collaboration with SCCL or any other coal mining company.

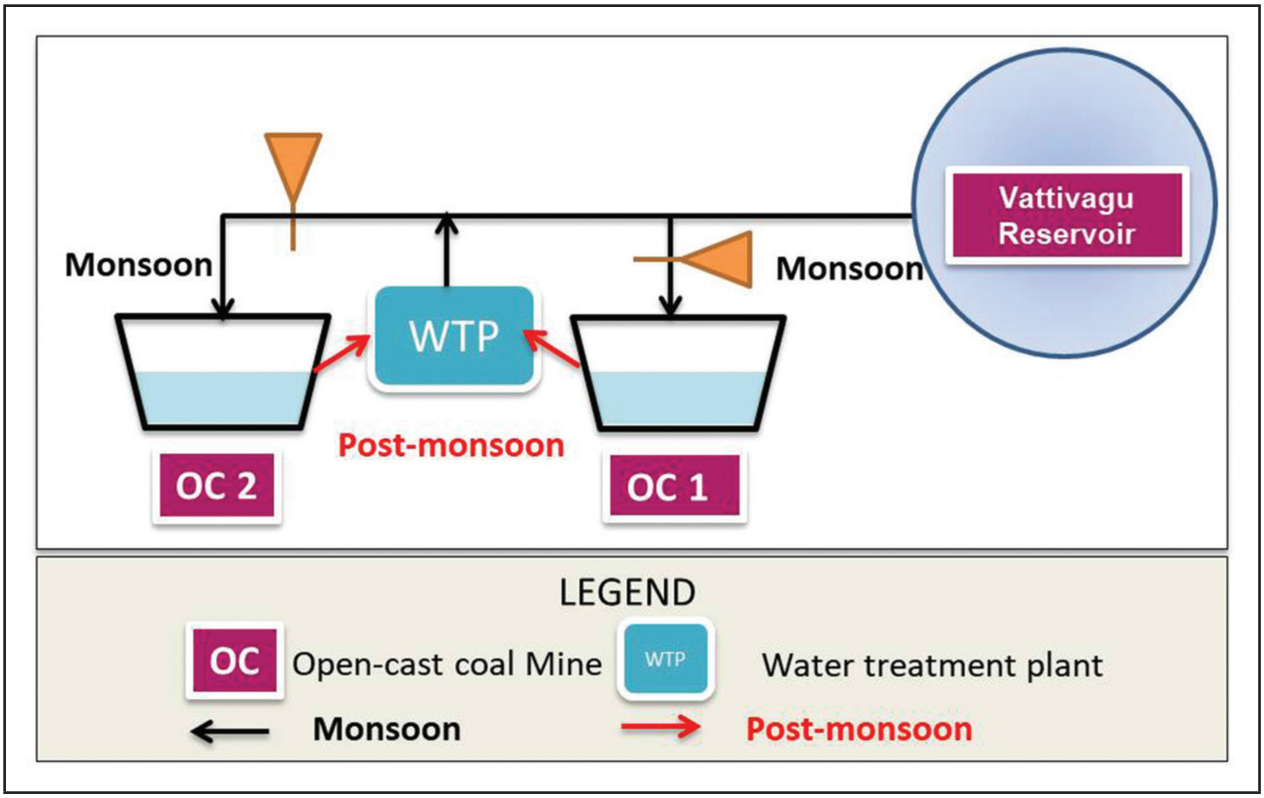

Figure 30: Proposed schematic depicting the potential for using the mined-out voids in Dorli OC-I and OC-II as balancing reservoirs connected with existing Vatti Vagu reservoir for storage and seasonal release of water for irrigation purpose

In order to develop appropriate methods for the design of pit lake systems, it is important to select research sites in the coalfields rather than in the laboratory. In this context, this research requires the selection of OCMs where mining operations have ceased recently but are yet to develop as pit lakes. However, several OCMs in India have extended lives beyond the life planned in their approved mining plans due to the mine owner's decisions to merge/amalgamate adjacent mines or to extend the operations to extract deeper coal reserves than what was planned earlier. Therefore, we have to choose an OCM which has been recently closed due to exhaustion of reserves and is therefore at the beginning of the mine closure process. It is possible to transform the final void into a pit lake water reservoir to supply water for irrigation during the post-monsoon months by implementing a scientific approach to the design and management of pit lakes. In the specific case of Dorli OCMs, it is worthwhile exploring a scheme for interconnecting the two Dorli OCMs with the Vatti Vagu reservoir for regulating the sustained flow of water across the summer/premonsoon and post monsoon seasons as shown in Figure 30. Since the voids created in Dorli OCMs can store more water than the Vatti Vagu reservoir itself, the surplus water during monsoon can be stored for subsequent use to increase the irrigated land for the local communities which will result in improvement in their standard of living even after the closure of these OCMs.

7. Summary and Recommendations

This report documents the key results of NIAS research on the impact of mining on the air and water environment in the Dorli-Bellampalli coalfield. The key findings and policy recommendations arising out of this study are as follows:

- The PM_{10} concentrations in the buffer zone of the OCMs in the Dorli-Bellampalli coalfield consistently exceed the standard during the active operation phase of these OCMs. Therefore, high production coal mines must utilize more environment friendly mining and transportation systems so as to control the fugitive dust. This also shows the importance of maintaining an effective "green belt" along the core zone limits to check the public exposure to the airborne respirable dust.

- Analysis of the spatial interpolation maps of PM_{10} and $PM_{2.5}$ included in this study indicate that OB dumps can also be major sources of air pollution even after mine closure. Therefore, it is critical to vegetate the slopes of the OB dumps immediately after mine closure to reduce air pollution after the mines are closed. This in turn requires the maintenance of proper slope angles in the OB dumps to ensure the success of tree planation even during heavy rains.

- In general, SO_2 and NO_2 concentrations in and around these OCMs are far below the NAAQ standards. This shows gaseous pollutants are less important than PM pollutants in coal mines in India.

- CPCB and/or the relevant SPCB must carry out source apportionment studies to identify and quantify the contributions of major emission sources to ambient pollutant concentrations in all areas containing coal mines.

- MoEF&CC must mandate all coal mines to upload the air and water quality data on their website immediately after they submit their statutory compliance reports and environmental statements to MOEF&CC and the SPCB. This mandate towards enhanced transparency and quality assurance will improve the effectiveness of regulation through public participation.

- A study of the impact of opencast coal mining on the air and water environment around four coal mines in the adjoining Dorli-Bellampalli coalfield indicates that SCCL has been successful in avoiding any adverse impact on the quality of water in the surrounding communities.

- According to the designated best use classes specified by the Central Pollution Control Board (CPCB), the present data on the water quality in the areas around the four OCMs in the Dorli-Bellampalli coalfield indicates the water quality here fits the criteria for Class D use for propagation of wildlife and fisheries or for Class E use for irrigation. The water quality can also meet the requirements for Class C use, i.e., the water can be used to meet the drinking water requirements of the local communities after adequate tertiary treatment. Therefore, as mandated by Section 20A of the MMDR Act (1957), there is a good potential for exploring more uses for pit lakes in this area to assess their utility to the local communities since no inter-disciplinary studies (combining science, technology, and social science) have been carried out to assess the current and upcoming pit lakes in terms of their utility to the surrounding communities with an integrated approach.

- The pH, electrical conductivity, and total dissolved solids values in the water samples drawn from this area are within the prescribed BIS/CPCB limits though they exceed the pre-mining values. While the dissolved oxygen values indicate higher levels of aeration in the surface water than in the groundwater. Therefore, the water collected in the pit lakes may be useful for domestic purpose (only after suitable treatment) or for irrigation after suitable steps are taken to prevent anthropogenic pollution and the formation of an anoxic layer in the pit lake.

- During the year FY 2017-18, 94 percent of India's coal production was extracted from 219 opencast coal mines. Over the next three decades, several of these coal mines will be closed in a progressive manner. As per the Mines and Minerals (Development and Regulation) Act (MMDR Act), Parliament has empowered the Central Government to issue policy directives for "promoting restoration and reclamation activities so as to make optimal use of mined-out land for the benefit of the local communities."

- Therefore, the Government may declare pit lakes as new resource-bases and as 'ecological hotspots' to channelize management strategies to achieve active ecosystem services from pit lakes. Possible uses would be to support fishes and avian biodiversity, as a reservoir for water to supplement the irrigation/industrial needs, or as a restored recreational ecosystem. Each of these end-usage scenarios demand implementation of different management options, cost-benefit analyses and stakeholder involvement. It is therefore important to commence research on optimal mine closure strategies and methods to ensure the creation of a sustainable ecosystem post mine closure in order to fulfil the mandate of MMDR Act.

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11 **Abstract:**

Coal continues to fuel more than 72 percent of the country's electricity generation and is also a vital input for other core industries like steel and cement. However, the coal sector must incorporate social and ecological sensitivities into the mining process from the planning stage up to final mine closure. In this report, the authors present the results of a study on the water and air environment spread over an area of 163 km^2 in and around four opencast coal mines in the Dorli - Bellampalli coalfield located in the State of Telangana. This study is based *inter alia* on the ambient air concentrations and water quality data extracted from the half-yearly compliance reports submitted by SCCL's four opencast coal mines between June 2012 and September 2019. In this study, the variations in airborne concentrations and water quality before and after stoppage of coal production from these opencast coal mines have also been compared in order to develop policy recommendations as well as areas for future research.

In general, the particulate matter (PM10 and PM2.5) concentrations in the buffer zone around the opencast coal mines in the study area are slightly higher than the corresponding CPCB standards (60 and 40 $\mu g/m^{3}$, respectively) when these mines are in operation. Therefore, opencast coal mines must implement more effective dust controls during all phases of the mining and mineral transportation processes and also maintain a suitable thick green belt to separate the core and buffer zones. The pH, electrical conductivity, and total dissolved solids values in the water samples exceed the pre-mining values but are within the prescribed BIS/CPCB limits. The dissolved oxygen values indicate optimal levels of aeration in the surface water. Pit lake systems evolved from open-cast coal mine voids have the potential to be a more cost-effective, environment-friendly and beneficial option for coal mine closure as opposed to the current mandate of backfilling the final void by re-handling the previously excavated and vegetated overburden dumps. According to the designated best use classes specified by the Central Pollution Control Board, the water quality around the opencast coal mines studied indicates the probable use of water for drinking (Class C) after adequate tertiary treatment, Class D for propagation of wildlife and fisheries, and Class E for irrigation. Therefore, it is possible to transform these final voids into water reservoirs for the benefit of the local communities by implementing a scientific approach to the design and management of pit lakes.

12 **Keywords:**
Air pollution; Mine Closure; Opencast coal mine; Pit Lakes; Water pollution

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